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TEXTBOOK OF HUMAN ANATOMY

For medical students

Volume 1

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In 2 volumes

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Edited by prof. M.R. Sapin

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В пособии изложен курс анатомии человека, необходимый для последую-
щего изучения медико-биологических и клинических дисциплин. Учебный мате-
риал изложен логично, компактно, на современном научном уровне и хоро-
шо иллюстрирован. Объем и глубина изложения материала соответствует уров-
ню подготовки, необходимому для студентов медицинских вузов.
Для студентов медицинских вузов, аспирантов, врачей.

PREFACE

This book consists of two parts and contains the most contemporary and fairly detailed data on the structure of the human body from the macroanatomic level to the microscopic one. The book also contains information about submicroscopic organization of cells and tissues. A lot of attention is given to topographic anatomy, correlation between the organs and bones of the skeleton and nearby organs, which brings theoretical anatomy to its practical purpose. This textbook provides a detailed description of the origin of the organs, their age peculiarities, variations and congenital malformation. As a whole, this book is structured in accordance with a plan, traditional in functional human anatomy.

In the first book a comprehensive introduction, in which necessary general anatomical terms and concepts are brought up, is followed by a detailed account of the structure of cells and tissues. Then follows the section on the anatomy of the skeletal and muscular system, in which the structure of skeletal bones, bone junctions, joints and skeletal muscles is expounded. Here information on topography of connective tissue structures, muscles of the head, body and limbs is also given. And finally, the functional anatomy of digestive and respiratory organs is presented.

The second book includes sections on the anatomy of the urinary organs, male and female genitals, endocrine glands and also organs of the immune system, which protect the organism from foreign substances. This book also contains a description of the heart and blood vessels (arteries, capillaries, veins), nervous system and sensory organs.

Part of the information is presented in well-designed informative tables.

Both books are richly illustrated with colorful anatomical pictures of organs, their parts, microscopic details. As is customary for anatomical textbooks the organs, their larger parts and anatomical objects that have a clinical significance are named both in English and Latin.

The Authors

INTRODUCTION

Human anatomy is a science about the genesis, development and structure of the human body. It studies external forms and proportions of the human body and its parts, separate organs, their constitution and microscopic structure. Anatomy also studies the main stages of human development, particularities of structure of the body and separate organs at different age periods.

Anatomy studies the structure of the human body taking into consideration biological patterns, natural for all living organisms. At the same time human beings differ very much from animals due to their living in society. Mankind was formed by labor and social needs, an increase in which led to changes in structure, to biological progress. The environment has an influence on the human organism as well.

In studying the structure of the human body it is important to consider age, sexual and individual differences. During infancy, adolescence and even juvenile age the growth of organs and differentiation of tissues still continues. In adulthood the structure of the body is more or less stable. Even during this period, however, alterations take place within organs under the influence of living conditions and the environment.

It is impossible to understand the distinctions of form and structure of the human body without an analysis of its functions, as it is impossible to imagine the function of any organ without an understanding of its structure.

The human body consists of many organs and a tremendous amount of cells, however it is not a sum of separate parts but a whole coordinated living organism. This is why it is impossible to examine organs without considering at their relationship with each other and without taking into account the integrative role of the nervous and vascular systems and the endocrine apparatus. The main methods of anatomical research are the following: observation, examination of the body, dissection and studying of separate organs and groups of organs (macroscopic, or gross anatomy), including their internal fine structure (microscopic anatomy).

With the appearance of microscopes anatomy gave start to histology (the study of tissues) and cytology (the science of structure and functions of the cell).

The structure of the skeleton, internal organs, the disposition of blood and lymphatic vessels are examined with the help of x-rays. In the clinic the internal surface of many internal organs is studied by means of endoscopy. Antropometrical methods are used for studying external forms and proportions of the body.

The study of the human body by the systems (skeletal, muscular, digestive, etc.) is called systematic (descriptive) anatomy.

Systematic anatomy studies the structure of «normal» that is, healthy human beings, whose organs have not been altered by disease or disturbance of development. The structure of the body is considered normal if it can provide the functions of a healthy organism. The standard values (for weight, height, shape, etc.) stand within a maximum and minimum and reflect individual structural features. Individuality of every human being is determined by hereditary and environmental factors. Recently the term «conditional standard» has often been used which indicates the relativity of this concept. Individual variability gives reason to discuss variants (variations) of structure of the organism and its organs. Variants are expressed as deflections from most frequently met cases, which are accepted as standard.

Strongly expressed congenital deflections from norm are called <u>anomalies</u>. Some anomalies do not change the external appearance (right-sided position of the heart, of all or some internal organs). Others have external manifestations and are called <u>deformities</u> (underdevelopment of the skull, limbs, etc.). Deformities are studied by <u>teratology</u>.

<u>Topographic</u> (surgical) <u>anatomy</u> studies the structure of the human body by regions, as well as the location of organs and their interrelation with each other and with the skeleton. External forms of the body and its proportions are studied by <u>surface anatomy</u>. Modern anatomy is called <u>functional</u>, as it examines the structure of the body in correlation with its functions.

Anatomy examines the structure and functions of organs taking into account the developments the human being goes through from birth to death (during ontogenesis). Developments that take place before birth (the prenatal period) are examined by <u>embryology</u>. After birth (the postnatal period) the human being is studied by <u>developmental anatomy</u>. Peculiarities of body structure of elderly and senile people are studied by <u>gerontology</u> — the science of aging.

In accordance with the length and width of the body and other anthropometric features anatomy distinguishes the dolichomorphic, brachymorphic and mesomorphic types of constitution. The dolichomorphic constitutional type is defined by a narrow long trunk and long extremities (asthenic); the brachymorphic type is characterized by a short wide trunk and short extremities (hypersthenic). The intermediate type of constitution is called mesomorphic. This type is close to an «ideal» (normal) human being (normosthenic).

While analyzing the peculiarities of structure of the human body (analytical approach), anatomy studies the organism as a whole, using the synthetic approach. That is why anatomy is not only an analytical science, but also a synthetic one.

PLANES AND AXES.
GENERAL ANATOMICAL TERMS

The concept of planes and axes (Fig. 1) is used for designation of the position of the human body in space and the location of its parts and organs relative to each other. The 'initi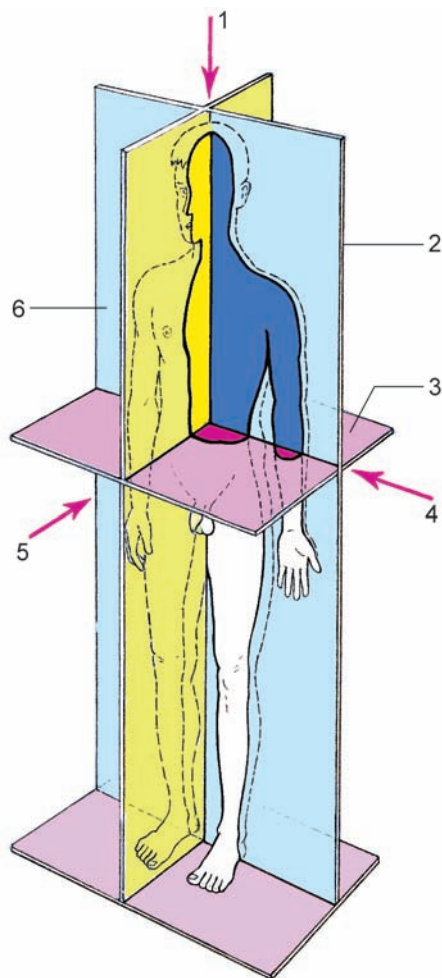al' position is that of a human being standing, feet together, palms forward. The human being, like other vertebrates, is built with double-sided (bilateral) symmetry; thus, the body may be divided into the right and left halves. The middle (median) plane is a border between them. It is situated vertically and oriented from front to back. This plane is called sagittal.

The vertical plane which is oriented perpendicularly to the sagittal one and which separates the anterior and posterior parts of the body is called frontal. Instead of the terms «anterior» and «posterior» to describe the location of organs the terms «abdominal» or «ventral» and «spinal» or «dorsal» are used. The horizontal plane is oriented perpendicularly to the sagittal and frontal ones and separates the upper and lower parts of the body.

These three planes (sagittal, frontal and horizontal) could be drawn through any point of the human body. Corresponding to the planes, directions (axes) are used to orient organs relative to the position of the body. The vertical axis is directed along the body of

Fig. 1. Axes and planes in human body.

1 — vertical (longitudinal axis); 2 — frontal plane; 3 — horizontal plane; 4 — transverse axis; 5 — saggital axis; 6 — sagittal plane.

a standing human being. The vertical column and nearby organs (spinal cord, thoracic and abdominal parts of the aorta, thoracic duct) are located along this axis. The vertical axis coincides with the lengthwise axis, which is oriented along the human body independently of its position in space, or along extremities (leg, arm), or along an organ the length of which prevails over its other proportions. The direction of the frontal (transverse) axis coincides with that of the frontal plane. This axis is oriented from right to left or from left to right. The sagittal axis is oriented from front to back like the sagittal plane.

The following is a list of anatomical terms used to define the location of organs and parts of the body: medialis, i.e. medial, if an organ (organs) lies closer to the median plane; lateralis, i.e. lateral (side), if an organ is situated further (to the right or left) from the middle plane; intermedius, i.e. intermediate, if an organ lies between two nearby formations; internus, i.e. internal (lying within) and externus, i.e. external (lying outside) when we are speaking about organs which are situated within the cavity of the body and outside of it; profundus, i.e. deep (lying deeper) and superficialis, i.e. superficial (situated at the surface) for defining the location of organs which lie at different depths.

Special terms are used for describing upper and lower extremities. For designation of the beginning of an extremity, that is, the part located closer to the trunk, the term proximalis, i.e. proximal (closest to the trunk), is used. Parts distant from the trunk are called distalis, i.e. distal. The anterior surface of the upper extremity is described by the term palmaris, i.e. palmar or volaris, i.e. located on the palm side; the lower extremity on the side of the sole is described as plantaris, i.e. plantar. The edge of the forearm at the side of the ulna is called ulnaris, i.e. ulnar. On the shin, the edge, at which the fibula is located, is called fibularis, i.e. fibular; the opposite edge, where the tibia is located is called tibialis.

For determining the projections of borders of the heart, lungs, liver, pleura and other organs provisory vertical lines oriented along the body are drawn on its surface. The front middle line (linea mediana anterior) passes along the front surface of the body, on the border between its right and left halves. The posterior middle line (linea mediana posterior) passes along the vertebral column, above the apexes of the spinous processes of the vertebrae. Several other provisory lines may be drawn between these two lines at each side, passing over anatomical structures on the surface of the body. The sternal line (linea sternalis) passes along the edge of the sternum; the mid-clavicular line (linea medioclavicularis) is drawn though the middle of the clavicle. This line often coincides with the papilla of the mammary gland and thus is also called linea mammillaris (mammillary

line). The anterior axillary line (linea axillaris anterior) begins at the homonymous plica in the axillary fossa and passes along the body. The middle axillary line (linea axillaris media) begins at the deepest point of the axillary fossa, and the posterior axillary line (linea axillaris posterior) begins at the homonymous plica. The scapular line (linea scapularis) passes through the inferior scapular angle; the paravertebral line (linea paravertebralis) passes along the vertebral column over the costotransverse joints (transverse processes of the vertebrae).

Questions for revision and examination

1. What is anatomy of the human body? Give the definition.
2. What does anatomy study?
3. Name the types of anatomy.
4. Name the research methods used in anatomy.
5. What is meant by the words: individual peculiarities of the structure of the human body?
6. Name the constitutional types. What anatomical peculiarities are characteristic of the different kinds of constitution?
7. What planes and axes that are used in anatomy, do you know?
8. What do you know about anatomical terms?

THE STRUCTURE OF THE HUMAN BODY

The human organism is a unified, complexly organized system. It consists of cells, tissues and organs. Organs, which are made of tissues, make up systems and apparatuses, which in combination form an entire human organism.

CELLS AND TISSUES

Each cell is a universal structural and functional unit of all living beings. Cells of all living organisms are similar in structure. Cells reproduce by division only.

CELLS

The cell (**cellula**), as an elementary well-organized unit, carries out the functions of reproduction, growth, metabolism, adaptation to changes in the environment and regeneration. Cells vary in shape, structure and chemical composition. In the human body there are flat, spherical, ovoid, cuboid, prismatic, pyramidal and stellate cells. The size of cells varies from several micrometers (small lymphocyte) to 200 micrometers (oocyte).

All cells have a plasma membrane, or cytolemma (which consists of hyaloplasm, containing organelles and inclusions), and a nucleus.

The cytolemma (*plasmalemma*) is 9–10 nm thick; it separates the content of the cell from its external (extracellular) environment (Fig. 2). The cytolemma performs functions of segregation, protection, transport and receiving impacts from the surrounding environment. It carries out the transfer of various molecules (particles) from outside into the cell and vice versa. The process of carrying substances inside the cell is called endocytosis, which can be differentiated into phagocytosis and pinocytosis. During phagocytosis the cell engulfs large particles (parts of dead cells, microorganisms). During pinocytosis the cytolemm forms vesicles, which involve small particles dissolved or suspended in the tissue fluid. These vesicles transport their content into the cell.

The cytolemma also takes part in excretion of substances out of the cell (exocytosis). Exocytosis is performed by means of vesicles or vacuoles, in which substances are excreted out of the cell.
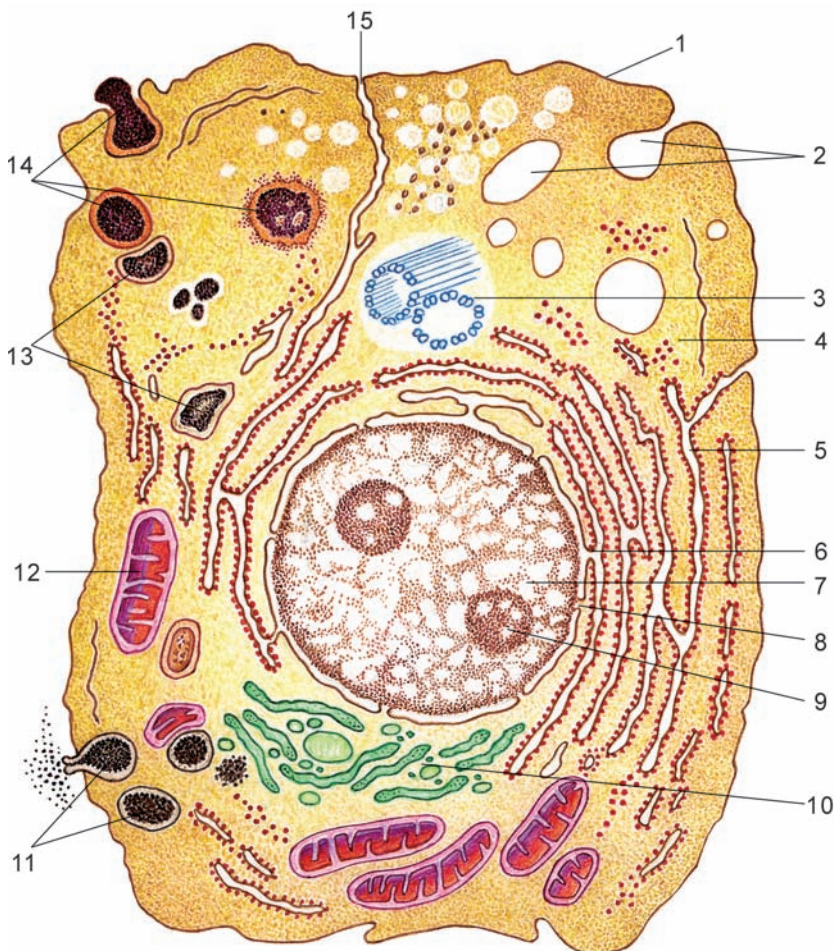
Fig. 2. Ultramicroscopic structure of the cell.

1 — cytolemma (cell membrane); 2 — pinocytotic vesicles; 3 — cytocenter; 4 — hyaloplasm; 5 — rough endoplasmic reticulum; 6 — connection between the perinuclear space and endoplasmic reticulum; 7 — nucleus; 8 — nuclear pores; 9 — nucleus; 10 — Goldi complex; 11 — secretory vacuoles; 12 — mitochondrion; 13 — lysosomes; 14 — phagocytozes (stages); 15 — connection between the cytolemma and membranes of endoplasmic reticulum.

The cytolemma also performs the function of reception. It is able to recognize chemical substances and physical factors, which is important for intercellular interaction. Receptors on the cell can differentiate biologically active substances (hormones, mediators and others).

The cytolemma, which is a semi-permeable biological membrane, has three distinguishable layers, namely, the external, intermediate and internal.
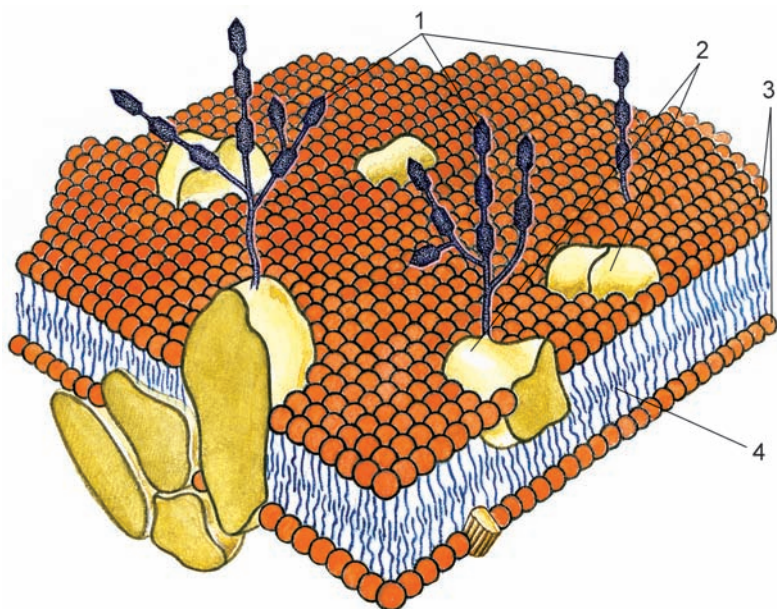
Fig. 3. Structure of the cytolemma
(of the cell membrane, acc. to A.Ham and D.Kormack).

1 — glycoproteides (endings of the proteid molecules); 2 — proteid molecules; 3 — lipids (binary lipid layer); 4 — hydrophobic «tails» of the lipid molecules.

The external and internal layers are electron-dense lipid monolayers (the bilayer). Between them there is an electron-light hydrophobic zone of lipid molecules about 3 nm in thickness (Fig. 3). Each monolayer of the lipid bilayer contains different lipids. The external monolayer contains cytochrome and glycolipids, whose carboniferous chains are directed outside the cell. The internal monolayer, which contacts the cytoplasm, contains cholesterol molecules and ATP-synthase. The cytolemma also contains protein molecules. Some proteins (intrinsic) penetrate the whole thickness of the cytolemm whereas others (intrinsic proteins) lie within the internal or external monolayer of the membrane. Membrane proteins can be receptors, enzymes or carriers (transport proteins).

The external surface of the cytolemma is covered with a thin layer (7.5–200 nm) of glycocalyx formed by glycoproteins and other carbohydrates.

On the surface of cells the cytolemm may form intercellular junctions, microvilli, cilia, invaginations and processes.

I n t e r c e l l u l a r j u n c t i o n s (c o n t a c t s) can be of three types: simple, denticulate and specialized (complex). In simple cell junctions the distance

between the cytolemma of neighboring cells is 15–20 nm. In denticulate junctions protrusions (serrations) of the cytolemma of one cell enter (wedge in) between such serrations of another cell.

In complex (adherent) cell junctions the cytolemma of neighboring cells are so close together that they merge with each other. This forms an occluding zone, which is impermeable for molecules. If an adherent junction is confined to a limited area an adhesion macula (desmosome) is formed. These types of junctions are met most commonly between epithelial cells.

Gap junctions (nexuses) are 2–3 mm in length with a distance between cytolemms of 2–3 nm. Ions and small molecules can easily pass through these junctions.

Microvilli are present on the surface of many cells. Microvilli are 1–2 mm in length and up to 0.1 mm in diameter. They increase the surface area of cells. On leukocytes and connective tissue cells they from the so-called brush border. Due to the presence of actin filaments microvilli have certain motility.

Cilia and flagella carry out the function of movement by making pendulum-like and wave-like motions. The ciliary epithelium of the upper respiratory tract, the seminiferous ducts and uterine tubes is covered with cilia of 5–15 mm in length and 0.15–0.25 mm in diameter. The center of each cilia contains an axial filament (axoneme), which is formed by a pair of peripheral microtubules. Flagella are similar in structure to cilia. They perform coordinated oscillatory motions due to the movement of the microtubules.

The hyaloplasm (*cytosol*) is a homogenous mass of complex composition, which occupies 53–55 per cent of the total volume of the cytoplasm. It contains proteins, polysaccharides, nucleic acids and enzymes. The hyaloplasm contains ribosomes used for protein synthesis. Various intermediate metabolism reactions take place here. The hyaloplasm contains the cells organelles and inclusions.

Organelles are indispensable cell microstructures, which perform certain vital functions. Organelles are divided into two types: membranous (membrane-bound) and non-membranous. The endoplasmic reticulum, the internal reticular apparatus /the Golgi complex/, mitochondria, lysosomes and peroxisomes are membrane-bound organelles and are separated from the hyaloplasm by membranes.

Membrane-bound cell organelles. The endoplasmic reticulum is formed by a multitude of membrane invaginations, folds, tubules, flat and round cisterns and membrane vesicles. There is granular (rough) and agranular (smooth) endoplasmic reticulum. The external surface of

rough endoplasmic reticulum is covered with ribosomes, while agranular endoplasmic reticulum does not have ribosomes. The granular endoplasmic reticulum performs synthesis (on ribosomes) and transport of proteins. Agranular reticulum synthesizes lipids and carbohydrates and plays a role in their metabolism (for example, steroid hormones in the adrenal cortex and in Leydig /interstitial/ cells of the testes; glycogen in liver cells). Endoplasmic reticulum also synthesizes membrane proteins and lipids for all cell organelles.

The internal reticular apparatus (the Golgi complex or apparatus) is a complex of pouches, vesicles, cisterns, tubules and sheets of membrane. Narrow canals connect sections of the Golgi complex with each other. Structures of the Golgi complex synthesize and store polysaccharides and protein-carbohydrate complexes, which are to be excreted from the cell. In most cells the Golgi complex is located around or near the nucleus; in exocrine cells it is situated over the nucleus in the apical part of the cell. Secretory vesicles are constantly separating from the outward side of the Golgi apparatus, while its membrane cisterns are continually being renewed. These vesicles supply the material for the cell membrane and the glycocalyx, which ensures the renewal of the plasma membrane.

Lysosomes are vesicles 0.2–0.5 mm in diameter, which contain nearly 50 different kinds of hydrolytic enzymes (proteases, lipases, phosphorylases, nucleases, glycosidases, phosphatases). Lysosomal enzymes are synthesized on ribosomes of the rough endoplasmic reticulum and are transferred by transport vesicles to the Golgi complex. Primary lysosomes then bud off from the Golgi complex vesicles. Lysosome membranes are stable to the enzymes included in them and protect the cytoplasm from effects of these enzymes. A change in permeability of a lysosomal membrane may result in activation of its enzymes and heavy damage to the cell, up to its destruction.

Inside mature (secondary) lysosomes (phagolysosomes) biopolymers are broken down to monomers, which are then transported through the lysosomal membrane to the hyaloplasm. Undigested substances stay inside the lysosomes, which, as a result, transform into high-electron density residual bodies.

Peroxisomes are vesicles 0.3–1.5 mm in diameter. They contain oxidative enzymes, which produce and decompose hydrogen peroxide. Peroxisomes participate in the breakdown of amino acids, metabolism of lipids (including cholesterol) and purines and neutralization of many toxic substances. It is considered that peroxisome membranes are formed by budding off smooth endoplasmic reticulum, and the enzymes are synthesized by polyribosomes.

M i t o c h o n d r i a are the so-called «cell power plants.» They participate in the processes of cellular respiration and transformation of energy into forms accessible for use by the cell. Mitochondria participate in oxidation of organic substances and in the synthesis of adenosine triphosphate /ATP/. Mitochondria can have a round, elongated or rod-like shape measuring 0.5–1.0 mm in length and 0.2–1.0 mm in width. Amounts, sizes and locations of mitochondria depend on the functions of the cell and its energy needs. There are many large mitochondria in cardiomyocytes and in the muscle fibers of the diaphragm. They are located in groups between myofibrils and are surrounded by granules of glycogen and elements of the smooth endoplasmic reticulum. Mitochondria are organelles with a double membrane. Between the external and internal membranes there is the intermembranous space 10–20 nm in thickness. The internal membrane forms multiple pleats or cristae. Usually the cristae are oriented perpendicularly to the long axis of the mitochondrion and do not reach the opposite side of the membrane. The cristae greatly increase the surface area of the inner membrane. Inside the mitochondrion between the cristae there is the fine-grained matrix, which contains small granules 15 nm in diameter (mitochondrial ribosomes) and fine fibers, which are molecules of deoxyribonucleic acid (DNA).

Mitochondria synthesize information, transport and ribosomal ribonucleic acids (RNA) on their own DNA molecules.

Numbers of mitochondria increase inside the cell by means of their division into smaller mitochondria, which grow increasing in size and are capable of dividing again.

Non-membranous cell organelles. Non-membranous cell organelles include centrioles, microtubules, filaments, ribosomes and polysomes.

C e n t r i o l e s, of which there are usually two (diplosome), are small bodies, surrounded by a dense region of cytoplasm . There are microtubules spreading away radially from the bodies, which make up a centrosphere. The two centrioles in a diplosome are positioned at a right angle to each other. Each centriole is a cylinder, whose wall consists of microtubules approximately 0.5 mm in length and 0.25 mm in diameter. The diplosome (pair of centrioles) with the centrosphere form the cell center, which is located near the nucleus of the cell or near the surface of the Golgi complex.

Centrioles are self-forming structures, which double during cell division. First, the two centrioles separate away from each other, and a daughter centriole forms at each of them. Thus, at the beginning of cell division there are two pairs of centrioles — two diplosomes — in each cell.

M i c r o t u b u l e s are hollow cylinders of different length 20–30 nm in diameter. The walls of microtubules are 6–8 nm in thickness. Microtu-

bules make up part of the centrosphere. There are also microtubules located beneath the cytolemma at the apical part of the cell, where they, together with bundles of microfilaments, form a three-dimensional intracellular network. Microtubules form the cell cytoskeleton and participate in the transport of substances within the cell.

T h e   c y t o s k e l e t o n of the cell is a three-dimensional network, in which different protein fibers are linked with each other by transverse bridges. As well as microtubules, the cytoskeleton also contains actin, myosin and intermediate filaments, which perform the support and motor functions of the cell.

R i b o s o m e s are found in all cells; they participate in the synthesis of protein molecules. Ribosomes, which are 20–30 nm in size, are complex ribonucleoproteins that consist of proteins and RNA molecules in a ratio of 1:1. Ribosomes can be found as singles (monoribosomes) or in groups (polyribosomes or polysomes). Ribosomes can be situated freely on a membrane surface, forming the granular endoplasmic reticulum.

Inclusions (*cellular granules*). Endocellular inclusions are formed in the course of cell activity and metabolic processes. Inclusions can be lipid, protein; they accumulate in the hyaloplasm as reserve resources necessary for the functioning of the cell. This type of inclusions is called trophic; it includes polysaccharides stored in the form of glycogen. Secretory inclusions contain biologically active substances and are accumulated in glandular cells.

Inclusions can also contain pigment, which either entered the organism from the outside (dye, dust particles) or formed in the organism as a result of its vital functions (hemoglobin, melanin, lipofuscin and others). Some pigmental inclusions are capable of coloring tissues of the human body including the skin integument.

TRANSPORT OF SUBSTANCES AND MEMBRANES IN THE CELL

Substances travel inside the cell encased in membranes. Transport of substances through membranes, including the cytolemma, is one of the most important functions of living cells. There are two types of transport, namely passive and active. Passive transport does not require energy; active transport is energy-dependant. Passive transport of non-polar molecules happens through diffusion from the area of greater concentration to the area of lower concentration (down the concentration gradient). The transport of polar substances depends on the difference in potentials across the cytolemma. As a rule, the internal surface of the cytolemma has a negative charge, which makes it easier for positively charged ions to move inside the cell.

Small molecules are carried through the membrane by selective transport proteins, which are built into the membrane. Each protein performs transport of one class of molecules or only one substance. Transmembrane proteins can either be carriers or may form canals. Neutral diffusion is possible for non-polar substances that pass between lipid molecules or through canal proteins of the cytolemm.

Carrier proteins perform active transport. This process uses energy, which is attained through ATP hydrolysis, or if there is a difference in potentials across the membrane. Herewith, active transport can proceed against the concentration gradient. The membrane potential on the cytolemm is supported by means of the sodium-potassium pump. This pump is an ATP-ase enzyme, which carries K^+ into the cell and Na^+ into the extracellular space against the concentration gradients. ATP-ases also perform active transport of amino acids and sugars.

Absorption by cells of different macromolecules and particles from outside is performed via endocytosis, and excretion—by means of exocytosis. Variations of endocytosis are phagocytosis, or absorption of particles, and pinocytosis, or absorption of dissolved substances. In the process of endo- or exocytosis transported substances are enclosed in membrane vesicles.

THE NUCLEUS

A nucleus is contained in all cells of the human body except for erythrocytes and thrombocytes (Fig.4). The function of the nucleus is to store hereditary information and to transfer it into daughter cells. This function is carried out by means of deoxyribonucleic acid (DNA) molecules in the nucleus. Synthesis of ribonucleic acids (RNA) and ribosomal material takes place in the nucleus as well.

Most cells have a spherical shape of oval nucleus. Other shapes of nuclei, however, may be found (circular, rod-shaped, spindle-shaped, beaded, bean-shaped, segmented, piriformed and polymorphous). Sizes of nuclei range from 3 to 25 mm. The largest nucleus is found in the ovum. Most cells in a human being contain one nucleus, but there are cells with two nuclei (for example some neurons, hepatocytes, cardiomyocytes). Some cells contain multiple nuclei (muscle fibers). The nucleus contains nuclear chromatin, a nucleolus and nucleoplasm.

The nuclear envelope (karyotek), which separates the contents of the nucleus from the cytoplasm, consists of the internal and external nuclear membranes, each 8 nm in thickness. The two membranes are separated by the perinuclear space (cisterns of the nuclear envelope), which contains
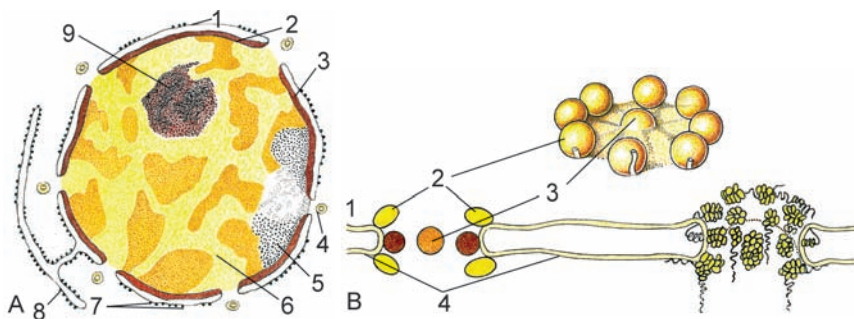
Fig. 4. Structure of the cellular nucleus (according to B.Alberts with co-authors, with deviations)

A. 1 — outer nuclear membrane; 2 — inner nuclear membrane; 3 — nucleolemnal cistern (nuclear envelope); 4 — nuclear pore; 5 — chromatin; 6-nucleoplasm; 7 — ribosomes; 8 — rough endoplasmic reticulum; 9 — nucleolus. B. Nuclear pore complex. 1-outer nuclear membrane; 2 — granules of the nuclear pore complex; 3 — central granule; 4 — inner nuclear membrane.

fine-grained material of moderate electron density. The external nuclear membrane passes into the rough endoplasmic reticulum. Thus, the perinuclear space makes up a continuous cavity with the endoplasmic reticulum. The internal membrane is connected by its inside surface with a network of protein fibrils.

The nuclear envelope has numerous round-shaped nuclear pores each 50–70 nm in diameter. Each nucleus has 3000–4000 pores. Along the sides of a pore the external and internal membranes are connected, forming the so-called pore ring. Each pore is closed by a diaphragm, also called the pore complex. The pore diaphragms are composed of protein granules, which are connected with each other. Selective transport of large particles and exchange of substances between the nucleus and the cytoplasm are performed through nuclear pores.

Beneath the nuclear envelope there is the nucleoplasm (karyoplasm), which has a homogenous structure, and the nucleolus. The nucleoplasm of a nucleus that is not dividing contains in its protein matrix osmiophilic granules (clumps) of heterochromatin. Areas containing loose chromatin situated between the granules are called euchromatin. Loose chromatin is also called decondensed chromatin. This is where synthetic processes are carried out most intensively.

During cells division chromatin becomes compact, condenses, forms chromosomes. No synthesis takes place on chromosomes.

Chromatin of a cell not in division and chromosomes of a dividing cell are made up of deoxyribonucleic acid (DNA) molecules, associated with ribonucleic acid (RNA) and proteins (histone and non-histone).

Each DNA molecule consists of two long right-involuted polynucleotide chains (double helices). RNA molecules are formed by a single polynucleotide chain. Each nucleotide consists of a nitrogenous base, sugar and phosphate group. The bases are directed to the inside of the double helix, and the sugar-phosphate frame is to the outside.

The hereditary information is presented (recorded) in the DNA molecule in a linear sequence of its nucleotides. The basic unit of heredity is a gene. A gene is a region of a DNA molecule, which contains a definite sequence of nucleotides and is responsible for the synthesis of one specific protein.

DNA molecules are compactly packed. Thus, one DNA molecule, which may contain 1 million nucleotides, positioned linearly, would take up a segment of just 0.34 mm. The length of a human chromosome stretched out is nearly 5 cm.

Chromosomes are oblong, rod-shaped structures, which have two shoulders separated by a groove called the centromere. There are three types of chromosomes characterized by the position of the centromere and mutual positions and lengths of the shoulders (stalks). Metacentric chromosomes have equal length shoulders; submetacentrics have shoulders of different length. Acrocentric chromosomes have one long shoulder and a second very short shoulder that is barely visible.

The surface of chromosomes is covered with different molecules, most of which are RNP (ribonucleoprotein). Somatic cells contain two copies of each chromosome. These are called homologous chromosomes. They are equal in length, form, structure, position and carry the same genes, which are located in the same loci. Structural peculiarities, number and sizes of chromosomes are called the karyotype. A normal human karyotype includes 22 pairs of autosomes and one pair of sex chromosomes (XX or XY). Somatic human cells have a double (diploid) number or chromosomes (46), while gametes contain a single (haploid) set (23 chromosomes). Thus, gametes contain two times less DNA than somatic cells.

One or several nucleoli can be detected in all non-dividing nuclei. The nucleolus consists of two different components: an electron-dense nucleolonema and a granular part. The nucleolonema contains a fibrous (fibrillar) part, which consists of interlaced RNA fibers approximately 5 nm in width. The granular component is formed by granules 15 nm in diameter, which are particles of RNP —precursors of ribosomal subunits. The nucleolus produces ribosomes.

CELL DIVISION. THE CELL CYCLE

Growth of the organism, increase in number of cells, their reproduction all take place through cell division. The main mechanisms of cell division in the human organism are mitosis and meiosis. The processes that take place during these two mechanisms are similar, however they lead to different results.

Mitotic cell division (mitosis) leads to an increase in number of cells and growth of the organism. This provides for the renewal of cells after their aging and death.

All cells in a state of reproduction (division) exhibit changes, which are part of the cell cycle. The cell cycle is a complex of processes, which takes place in the cell during its preparation for division and division itself, as a result of which one (mother) cell divides into two daughter cells. The cell cycle includes the preparation of the cell for division (interphase) and mitosis (the process of division).

During interphase, which lasts about 20–30 hours, the speed of biosynthetic processes and the number of organelles increase. At this time the mass of the cell and all its structural components, including the centrioles, is doubled. The molecules of nucleic acid are replicated (duplicated). This process is aimed at transferring the genetic information stored in parental DNA into the daughter cells by means of its exact reproduction. Each parental DNA strand serves as a matrix for the synthesis of a daughter copy of deoxyribonucleic acids. At the end of replication each daughter DNA molecule contains one old and one new strand. During preparation for mitosis all the proteins necessary for cell division are synthesized. The end of interphase condenses the chromatin in the nucleus.

Mitosis is a period during which the mother cell divides into two daughter cells. Mitotic cell division provides for even distribution of cell structures and nucleic substance (chromatin) between two daughter cells. Mitosis can last from 30 minutes to 3 hours. It is divided into prophase, metaphase, anaphase and telophase (Fig. 5). During prophase the nucleolus gradually disintegrates, and the centrioles diverge to opposite poles of the cell. During metaphase the nuclear membrane breaks down, and spindle fibers are formed between the poles and equator of the cell. Endoplasmic reticulum and Golgi complex structures break up into small vesicles, which, together with mitochondria, spread into both halves of the dividing cell. At the end of metaphase each chromosome begins to split by a longitudinal fissure into two daughter chromosomes. During anaphase the daughter chromosomes become separated and diverge to the cell poles at a speed of 5 mm per minute. At the end of anaphase the plasma membrane
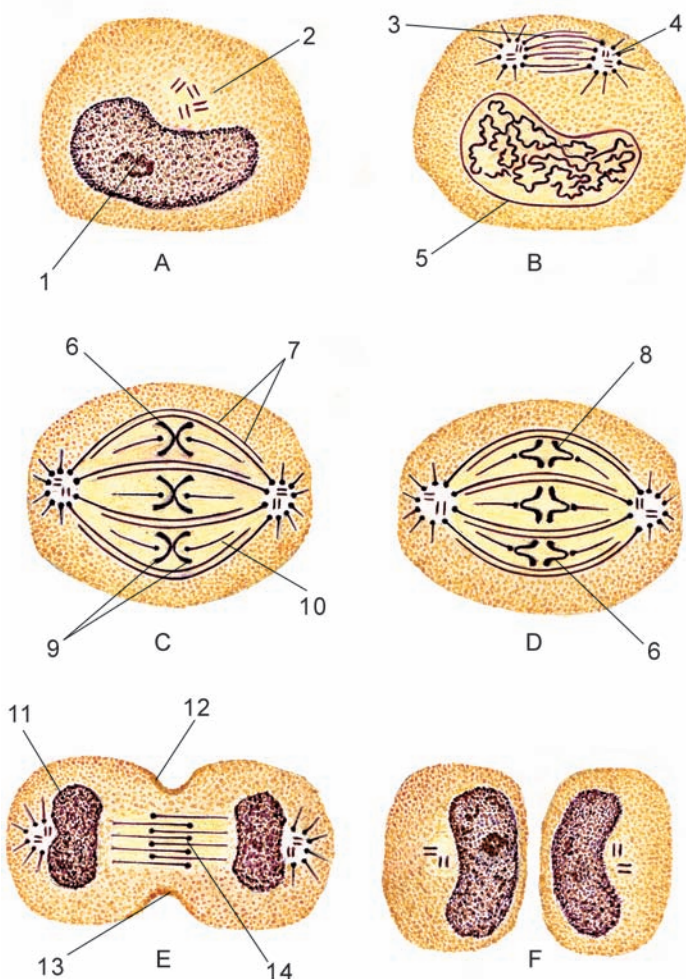
Fig. 5. Stages of mitosis. Aggregations of chromatin, formation of chromosomes, formation of the spindle apparatus and regular positioning of chromosomes as well as centrioles within both cells are clearly evident.

A — interphase; B — prophase; C — metaphase; D — anaphase; E — telophase; F — late telophase (acc. to A.Ham, D. Kormack, 1982, with deviations). 1 — nucleolus, 2 — centrioles, 3 — mitotic spindle, 4 — aster; 5 — nucleolemme; 6 — kinetochore; 7 — contineous microtubules; 8,9 — chromosomes; 10 — chromosomal microtubules; 11 — formation of nucleus; 12 — fissure of granulation; 13 — bundle of actin fibers; 14 — residual corpuscle.

forms a division furrow perpendicular to the cell's lengthwise axis. During telophase chromosomes, which have moved to the poles, become decondensed, transform into chromatin, and transcription (production) of

RNA begins. The nuclear membrane, the nucleolus and membrane structures of future daughter cells are quickly formed. At the surface of the cell a groove along its equator divides it into two daughter cells. Through mitotic division daughter cells receive a set of chromosomes identical to that of the mother cell. Mitosis provides genetic stability, increase in number of cells and, consequently, growth of the organism as well as regeneration processes.

Meiosis takes place in sex cells. The results of this type of division are new cells with a single (haploid) set of chromosomes. This is important for passing on genetic information. During the fusion of two gametes of opposite sexes (during fertilization) the set of chromosomes becomes double (diploid). The diploid cell (the zygote), which forms as a result of fertilization, contains two complementary (homologous) sets of chromosomes. One chromosome of each homologous pair originates from the nucleus of the ovum, the other from the nucleus of the spermatozoon.

During meiosis of sex cells each daughter cell receives only one chromosome out of each homologous pair. This becomes possible due to two successive meiotic divisions. As a result, one diploid cell produces four haploid daughter cells. Each haploid cell contains twice as less chromosomes (23) as the nucleus of the mother cell (46). Also as a result of meiosis the haploid sex cells contain not only less chromosomes, but an altered combination of genes. Thus, the new organism carries not only a sum of the parents features, but its own individual characteristics as well.

Questions for revision and examination

1. Name the structural elements of the cell. Give their morpho-functional characteristics.
2. List the membranous and non-membranous cell organelles. Name their functions.
3. What elements is the nucleus composed of? What functions does the nucleus perform?
4. Describe the structure of a DNA molecule.
5. Give the morphological characteristics of chromosomes; give their classification.
6. What is the cell cycle? What periods /phases/ can be distinguished in it?
7. What is meiosis? What are the differences between meiosis and mitosis?

TISSUES

Cells and their derivatives combine to form tissues. A tissue is a combination of cells and extracellular matrix united by a common embryological derivation, structure and function. The tissues in the human organism are subdivided into four types: epithelial, connective, muscular and nervous. Each type of tissue develops from a specific germ layer. Epithelial

tissue derives from the endo-, ecto- and mesoderm. Nervous tissue develops from the ectoderm.

EPITHELIAL TISSUE

Epithelial tissue covers the surface of the body and mucosas. Epithelial tissue also forms glands (glandular epithelium). Furthermore, there is sensory epithelium in the hearing, vestibular, smell and taste organs, the cells of which can perceive specific stimuli.

Classification of epithelium. Integumentary epithelium is subdivided into single layer (simple) and stratified (Fig. 6). In simple epithelium all cells lie on the basement membrane. In stratified epithelium cells lie in several layers, and only cells of the basal (deep) layer are in contact with the basement membrane. Simple epithelium is further subdivided into single-row (isomorphic) and multilayered (pseudostratified). In single-row epithelium the nuclei of all cells are situated on the same level and cells have the same height. In pseudostratified epithelium nuclei lie in several layers, while the cells may have different shapes. Depending on the shape of the cells and their ability to undergo keratinization epithelium can be stratified keratinous (squamous), non-keratinized (squamous, cuboidal, columnar) and transitional. All epithelial cells have certain common structural peculiarities. The apical part of epitheliocytes differs from the basal part. Cells of the integumentary epithelium form layers, which rest on the basement membrane and lack blood vessels. Epithelial cells contain all the general organelles. Cells, which secrete protein, are rich in granular endoplasmic reticulum. Cells, which produce steroids, have more smooth endoplasmic reticulum. Absorption cells posses an abundance of microvilli, and epitheliocytes, that cover the respiratory tract mucosa, have cilia.

The integumentary epithelium performs the barrier and protective functions as well as the functions of absorption (small intestine epithelium, peritoneum, pleura, nephron canals, etc.), secretion (amniotic epithelium, stria vascularis of the cochlear duct), ventilation (respiratory alveolocytes).

Simple epithelium. Simple epithelia include simple squamous, cuboidal, columnar and pseudostratified epithelium types. Simple squamous epithelium is a layer of flat cells, which lie on a basement membrane. Protrusions of cell surfaces can be found only above zones containing the nucleus. Epitheliocytes have a polygonal shape; they form the external wall of the renal glomerulus capsule; cover the posterior surface of the cornea; line blood and lymph vessels and chambers of the heart; cover the serous membranes (mesothelium).
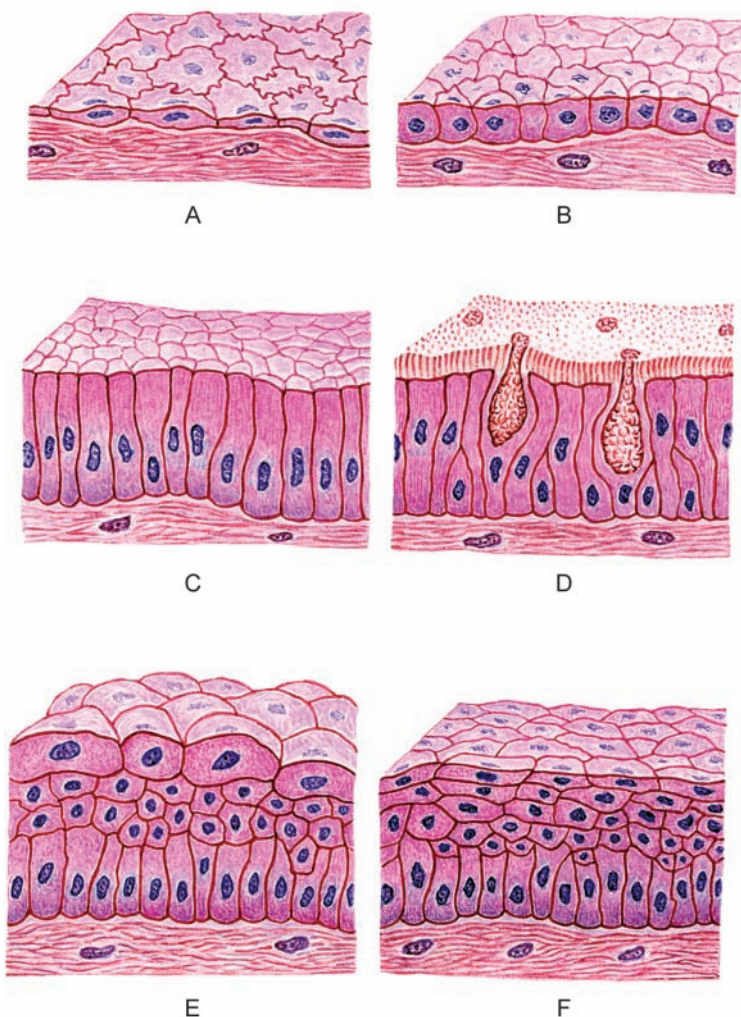
Fig. 6. Structure of the epithelial tissue.

A — simple ciliated epithelium (mesothelium); B — simple cuboidal epithelium; C — simple colum-
nar epithelium; D — ciliar epithelium; E — transitional epithelium; F — stratified squamous nonkera-
tinized epithelium.

Endotheliocytes have an elongated or fusiform shape and a very thin
layer of cytoplasm. The perinuclear part of the cell is thickened and pro-
trudes into the lumen of the blood vessel. Microvilli are situated mostly
above the nucleus. The cytoplasm contains micropinocytotic vesicles,
solitary mitochondria, elements of the rough endoplasmic reticulum and
the Golgi complex. Mesotheliocytes, which cover serous membranes (peri-

Fig. 7. Structure of the columnar simple epithelium.
1 — microvilli; 2 — nucleus; 3 — basal membrane; 4 — connective tissue.
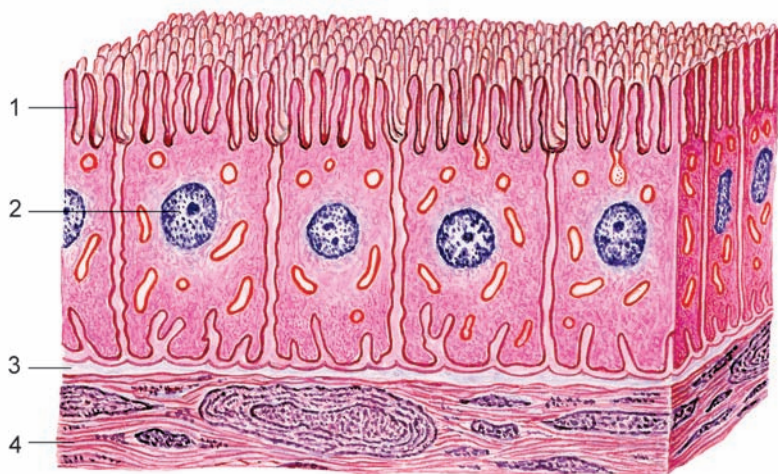
toneum, pleura, pericardium), partake of endotheliocytes. Their free surface is covered with a multitude of microvilli; some of the cells contain 2–3 nuclei. Mesotheliocytes facilitate the gliding of internal organs against each other and prevent the formation of adhesions between them. Respiratory epitheliocytes are large (50–100 mm), their cytoplasm is rich in micropinocytotic vesicles and ribosomes. Other organelles are not abundantly represented.

S i m p l e   c u b o i d a l   e p i t h e l i u m is formed by a single layer of cells of hexagonal shape. The nucleus is round and lies in the center of the cell. There are non-ciliary cuboidal epitheliocytes (the collecting ducts in kidneys, distal straight tubules, biliary ductules, the choroid plexus in the brain, the pigmental epithelium of the retina, etc.) and ciliary cuboidal epitheliocytes (terminal and respiratory bronchioles, ependymocytes which line the ventricles in the brain). The anterior surface of the crystalline lens is also covered with cuboidal epithelium. The surface of these cells is smooth.

S i m p l e   c o l u m n a r (p r i s m a t i c) e p i t h e l i u m (Fig. 7) covers the mucosa of the gastrointestinal tract organs beginning at the entrance into the stomach up to the anal opening; it also covers the walls of the papillary ducts and collecting tubules in kidneys, striated ducts of the salivary glands, the bronchi, the uterus and uterine tubes. Columnar epitheliocytes are tall prismatic polygonal or round cells closely adjoined to

24

each other. A round or ellipse-shaped nucleus is usually situated in the lower (basal) third of the cell. Often prismatic cells posses an abundance of microvilli, stereocilia or cilia. Cells with microvilli prevail in the mucosal epithelium of the stomach, intestine and bladder.

P s e u d o s t r a t i - f i e d (m u l t i - l a y e r e d) e p i t h e l i u m is formed mainly by cells with an oval nucleus. The nuclei of these cells are situated at different layers. All of these cells rest on the basement membrane, however not all of them reach the lumen of the organ. This type of cells is subdivided

Fig. 8. Stratified squamous nonkeratinized epithelium (acc. to V.G. Eliseev and others).

1 — superficial layer; 2 — basal layer; 3 — underlying connective tissue.

into three kinds. The highly differentiated surface epitheliocytes extend to the lumen of the organ. These cells have a round nucleus and well-developed organelles, especially the Golgi complex and the endoplasmic reticulum. Their apical plasma membrane is covered with microvilli, stereocilia or cilia. Ciliary cells cover the mucosa of the nose, trachea and bronchi. Non-ciliary cells cover the mucosa of part of the male urethra, excretory ducts of various glands, the epididymal and deferent ducts. Interposed epitheliocytes are not well differentiated, do not have cilia or microvilli and do not extend to the lumen of the organ. They are situated between the surface cells. Basal epitheliocytes form the lowest (deep) cell layer. Basal epitheliocytes are the source of epithelium renewal (2% of the cell population is renewed daily).

Stratified epithelium. Stratified epithelia include non-keratinized and keratinized squamous epithelia and stratified cuboidal and columnar epithelia.

S t r a t i f i e d   s q u a m o u s   n o n - k e r a t i n i z e d   e p i t h e l i u m (Fig. 8) covers the mucosa of the mouth, esophagus, the transition zone of the anal canal, the vocal folds /cords/, the vagina, female urethra and the

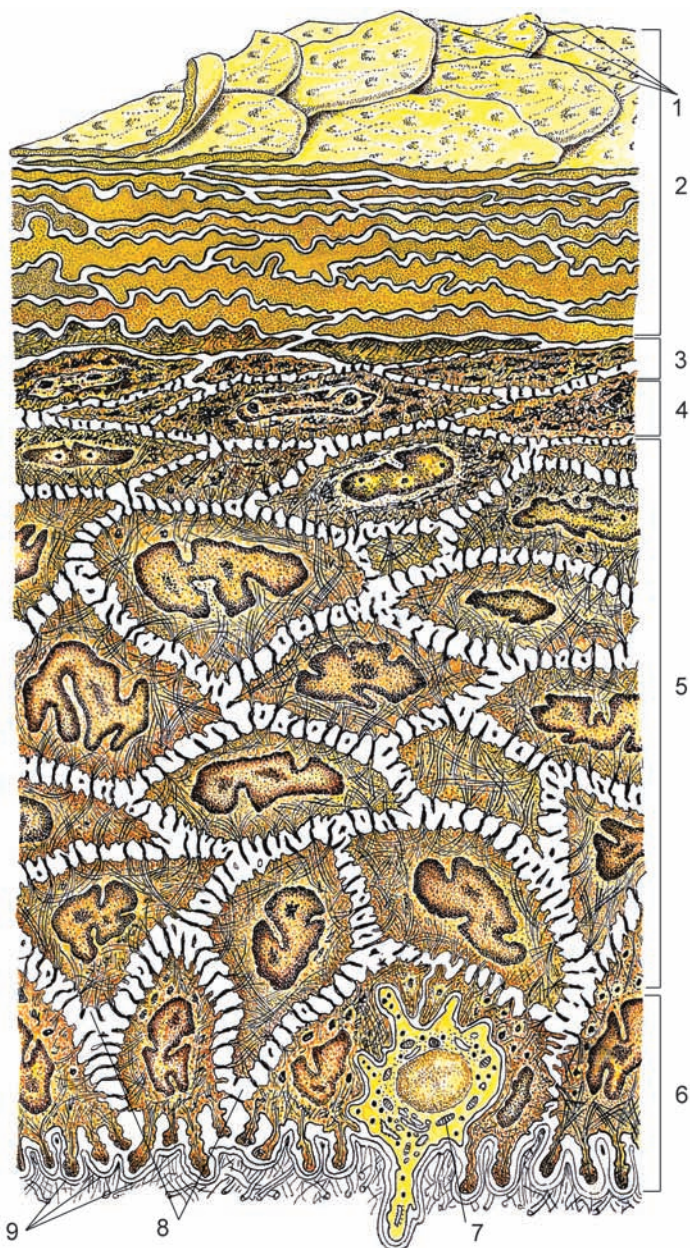**Fig. 9.** Structure of the stratified squamose keratinized epithelium (acc. to R. Krstic, with deviations).

1 — squamose flakes; 2 — keratoid layer; 3 — sparkling layer; 4 — granular layer; 5 — spinous layer; 6 — basal layer; 7 — melanocyte; 8 — intercellular fissures; 9 — basement membrane.

external surface of the cornea. This type of epithelium is subdivided into basal, spinous (middle) and surface layers. The basal layer is formed by large prismatic or polyhedral cells, which lie on a basement membrane. The middle spinous layer is formed by large polygonal cells. These two layers form the germinal layer. Epitheliocytes divide through mitosis, move upwards, flatten out and substitute for cells, which are shed off the surface. The surface layer is formed by flattened cells, many of which have lost their nuclei. The cells closest to the surface become flat, dead, lose contact with each other and fall off.

Stratified squamous keratinized epithelium (Fig. 9) covers the entire surface of the skin forming the epidermis. The epidermis consists of five layers, namely, the basal layer, the spinous layer, stratum granulosum, stratum lucidum and stratum corneum (keratinized layer). The basal layer consists of prismatic cells, which have numerous processes and are surrounded by the basement membrane. The cytoplasm above the granular nucleus contains grains of melanin. In between basal epitheliocytes lie pigment cells called melanocytes. The spinous (prickle cell) layer is formed by several rows of large polygonal prickle cells. Both previous layers form the germinal layer, the cells of which undergo mitotic divisions and move towards the surface. Stratum granulosum consists of flat (squamous) epitheliocytes, which are rich in keratohyaline. As its amount increases, cells slowly degenerate. Stratum lucidum has a strong light-bending ability, which is due to eleidin containing flat epitheliocytes. The keratinized layer is formed by shedding flakes of keratin.

Stratified cuboidal epithelium is formed by several (3 to 10) layers of cells. The surface layer consists of cuboidal cells. These cells have microvilli and contain grains of glycogen. Beneath the surface layer there are several layers of elongated fusiform cells. Directly on the basement there are polygonal and cuboidal cells. This type of epithelium is rare. It is found on small areas along short sectors between multinuclear columnar and stratified squamous non-keratinized epithelium posterior part of the nasal vestibule, excretory ducts of sweat glands.

Stratified columnar epithelium also consists of several layers of cells (3–10). Surface epitheliocytes have a prismatic shape and may bear cilia. Epitheliocytes that lie beneath are polyhedral or cuboidal. This type of epithelium is found in some areas of the salivary and mammary glands excretory ducts, larynx and male urethra.

Transitional epithelium. In transitional epithelium the number of layers can change (decrease) when the mucosa of the organ is stretched. This type of epithelium lines the mucosa of the renal pelvis, ureters, bladder and beginning of the urethra. The plasma membrane of the surface layer

is plicated, and its outer layer is thicker than the inner one. In an empty bladder the cells are tall, with 8–10 rows of cells seen on a section. In a full bladder cells are flattened with no more than 2–3 rows of cells, while the plasma membrane of the surface layer is smooth.

Glandular epithelium. Cells of the glandular epithelium (glandulo-cytes) form unicellular glands and the parenchyma of multicellular glands. Glands are subdivided into exocrine (have an excretory duct) and endocrine (no excretory ducts). Endocrine glands excrete their product directly into intercellular space, from which they enter the blood and lymph. Exocrine glands excrete their product through ducts onto the surface of the body or into lumens or organs (sweat, sebaceous, gastric and intestinal glands). Mixed glands contain an endocrine and exocrine parts (the pancreas).

The human organism contains many unicellular goblet exo-crinocytes, which lie between other epithelial cells lining the mucosa of hollow organs of the digestive, respiratory, urinary and reproductive systems (Fig. 10). These exocrinocytes produce mucus, which consists
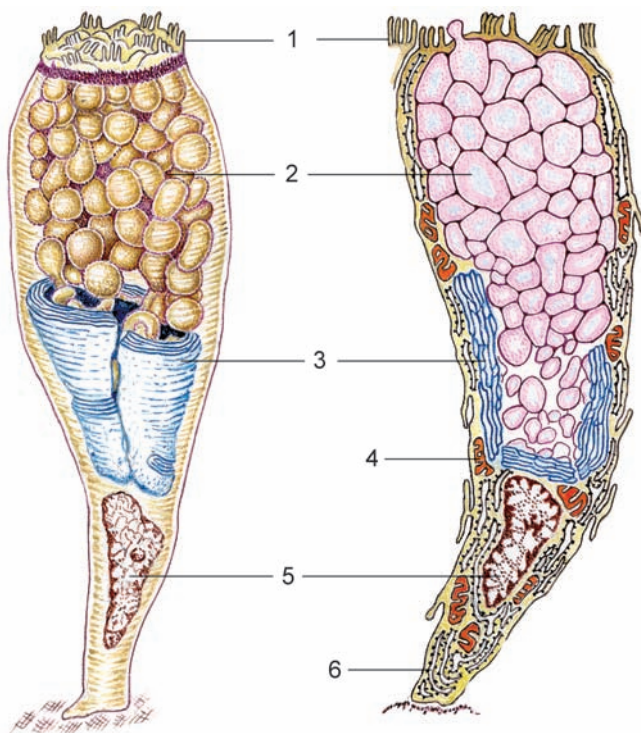

Fig. 10. Structure of a goblet cell.

1 — cellular microvilli; 2 — mucous (vesicle) granules; 3 — Golgi complex; 4 — mitochondrion; 5 — nucleus; 6 — rough endoplasmic reticulum.

of glycoproteins and lines the mucosa with a thin layer. The structure of goblet cells depends on the phase of the secretory cycle they are in. The narrow, chromatin rich nucleus lies in the basal part of the cell, or its stalk. There is a well-developed Golgi complex located above the nucleus. The upper dilated part of the cell contains many secretory granules, which undergo merocrine secretion. Once the granules are secreted the cell becomes narrow.

Secretion of mucus from a cell onto the mucosa surface usually takes place through exocytosis.

E x o c r i n o c y t e s also form the beginning excretory portions of multicellular exocrine glands and their tubular ducts. The morphology of exocrinocytes depends on the type of secretion and the secretory phase. Glandular cells are structurally and functionally polarized. Their secretory vesicles and granules are concentrated in the apical (supranuclear) zone and are excreted through the apical microvilli-bearing cytolemma. These cells are rich in mitochondria, Golgi complex and endoplasmic reticulum structures. Rough endoplasmic reticulum prevails in protein synthesizing cells (e.g. granulocytes or the parotid gland). Smooth reticulum is found in cells, which synthesize lipids and carbohydrates (e.g. cortical endocrinocytes of adrenal glands).

Secretory processes in exocrinocytes take place in cycles, which are divided into four phases. During the first phase the substances necessary for synthesis enter the cell. The second phase is the synthesis of the product, which is carried in transport vesicles to the Golgi complex. In the Golgi complex substances, which are to be excreted, are collected in vacuoles. Vacuoles turn into secretory granules, which move in the apical direction. During the third phase the secretory granules are excreted from the cell. During the fourth phase the exocrinocytes are restored.

There are three types of secretion. By m e r o c r i n e (e c c r i n e) secretion the products are excreted by exocytosis. This type is found in serous (protein) glands. The cell structure is not impaired. A p o c r i n e s e c r e t i o n (e.g. in lactocytes) is accompanied by destruction of the apical part of the cell (macroapocrine secretion) or only the apices of microvilli (microapocrine secretion). During h o l o c r i n e s e c r e t i o n the glandulocytes are completely destroyed and their protoplasm becomes part of the secretion (e.g. sebaceous glands).

Classifications of multicellular glands. According to the structure of the initial (secretory) portion glands are subdivided into tubular (in the form of a tube), acinar (shaped like a pear or an oblong grape) and alveolar (rounded, spherical). There are also tubuloacinar and tubuloalveolar glands (Fig. 11).
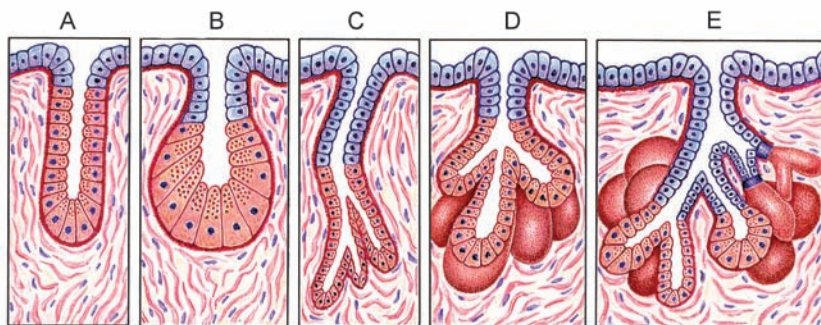
Fig. 11. Types of exocrine glands (acc. to I.V. Almasov and L.S.Sutulov).

A — simple tubular gland with noncompound terminal region; B — simple alveolar gland with noncompound terminal region; C — simple tubular gland with compound terminal region; D — simple alveolar gland with compound terminal region; E — composed tubular-alveolar gland with compound terminal region.

Depending on the structure of their duct glands can be simple, with only one duct, and compound. In compound glands the main duct collects many duct branches, each of which collects several secretory portions. Glands produce different types of secretion: protein (secretory glands), mucus (mucous glands) or mixed.

Questions for revision and examination

1. Give a classification of epithelia.
2. Name the cells found in simple epithelium. Give examples of each type of simple epithelium and characterize them.
3. What is pseudostratified epithelium and how does it differ from stratified epithelium?
4. What is stratified epithelium? List the layers that are distinguished in it.
5. Name the types of stratified epithelium and give a description of each.
6. What is transitional epithelium? How does it differ from other types of epithelium?
7. How does glandular epithelium differ from the other types?
8. Give the classification of endocrine glands.
9. Name three ways of secretion from gland cells. How do they differ from each other?

CONNECTIVE TISSUE

Connective tissues make up a large group, which includes fibrous connective tissues (loose and dense), specialized tissue (reticular, pigmental, adipose), rigid (bones and cartilage) and liquid (blood and lymph) ones. Connective tissues perform many functions. For example, fibrous connective tissues, cartilage and bones provide support; blood has a trophic

(nourishing) and protection (e.g. phagocytosis) functions. Connective tissues are made up of cells and extracellular matrix, which consists of glycosaminoglycans, proteoglycans and various fibers (collagen, elastic, reticular). Extracellular matrix is solid in bone tissue and liquid in blood.

Fibrous connective tissues include loose (areolar) and dense (collagenous) types dense connective tissue in turn subdivides into irregular and regular.

Loose fibrous connective tissue (Fig. 12) (LFCT) is located mainly around blood and lymph vessels and nerves; it covers muscles and forms the stroma of most internal organs, lamina propria mucosae, submucosa,

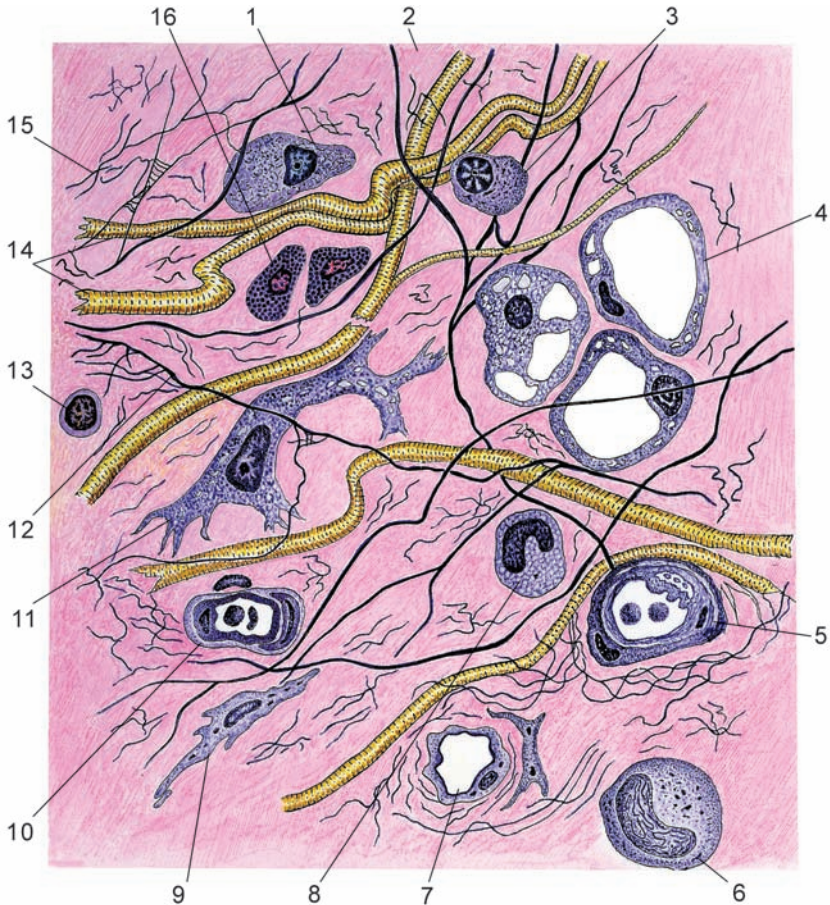**Fig. 12.** Structure of the loose collagen connective tissue.

1 — macrophage; 2 — fundamental (amorphous) substance; 3 — plasmocyte; 4 — adipose cell; 5 — blood vessel; 6 — monocyte; 7 — lymphatic capillary; 8 — eosinophillic granulocyte; 9 — fibrocyte; 10 — blood capillary; 11 — fibroblast; 12 — elastic fiber; 13 — lymphocyte; 14 — collagen fibres; 15 — reticular fibers; 16 — basophilic granulocyte.

subserosa and adventitia. Loose connective tissue contains many cells such as fibroblasts, fibrocytes, reticular cells, as well as wandering macrophages, mast cells (tissue basophils), plasma cells, adipocytes, pigment cells, lymphocytes and leukocytes. All these cells are situated in the extracellular matrix. The matrix is secreted by fibroblasts and consists of collagen, elastic and reticular fibers and a ground (amorphous) substance.

F i b r o b l a s t s are the main fixed cells, the quantity of which may vary in different types of connective tissue. Particularly large numbers of fibroblasts are found in loose fibrous connective tissue. Fibroblasts have an oval nucleus and a basophilic cytoplasm, which contains many free and fixed ribosomes. Fibroblasts are surrounded by fibers and clusters of collagen. The surface of these cells has thin cytoplasmic projections. Fibroblasts have a well-developed granular endoplasmic reticulum and Golgi complex. There are elongated membrane granules found in these cells, which contain fibrillar material. The cytolemma of fibroblasts carries many receptors. The cytoplasm contains filaments 5–7 nm in diameter. Micropinocytotic vesicles on the inside surface of the cytolemm suggest intensive endocytosis. The cytoplasm contains a three-dimensional microtrabecular network, which includes actin, myosin and intermediate filaments. Movement of fibroblasts is realized through activity of actin filaments.

Fibroblasts secrete the main components of the extracellular matrix, including collagen fibers (Fig. 13). These also include polysaccharides, namely, glycosaminoglycans (GAGs), which used to be called mucopolysaccharides. All sulfated GAGs are bound with proteins forming proteoglycans (old term—mucoproteins).

C o l l a g e n   f i b e r s initially develop as aggregates of procollagen, which turn into tropocollagen during secretion from the fibroblast. Tropocollagen molecules join to form protofibrils, which, in turn, form microfibrils 10 nm in diameter. The microfibrils form long transversely striped fibrils up to 300 nm in diameter. These fibrils make up collagen fibers (1–20 mm in diameter). Collagen fibers join to form bundles up to 150 mm in diameter.

E l a s t i c   f i b e r s (1–10 mm in diameter) are made up of protein elastin. Molecules of proelastin are synthesized by fibroblasts and smooth myocytes and secreted into the extracellular space, where microfibrils are formed. Elastic microfibrils (about 13 nm in diameter) make up elastic fibers, which form reticula, fenestrated laminae and membranes. Unlike collagen fibers elastic fibers are able to stretch (by 1.5 times) and return to their initial state.

R e t i c u l a r   f i b e r s are thin (100 nm to 1.5 mm). They are produced by fibroblasts and reticular cells. Reticular fibers and reticular cells form the reticular framework (stroma) of blood-forming and immune sys-
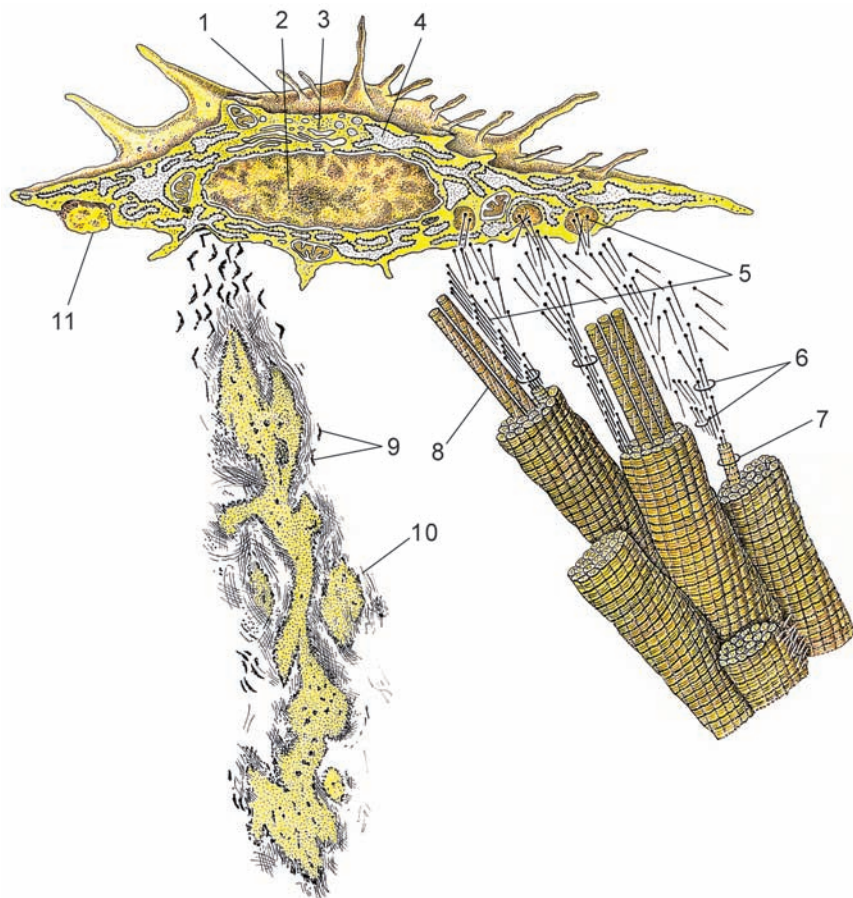
Fig. 13. Structure of the fibroblast and synthesis of the intercellular substance.

1 — fibroblast; 2 — nucleus; 3 — rough endoplasmic reticulum; 4 — reticular apparatus; 5 — molecules of the tropocollagen, outcoming from the cell; 6 — polimerisation of molecules of tropocollagen into protofibrilles; 7 — microfibrilles; 8 — fibrilles; 9 — molecules of the elastine; 10 — microfibrillar structural glycoprotein; 11 — elastic fiber within the membrane of a fibroblast.

tem organs. Together with collagen and elastic fibers they take part in forming the stroma of other organs. Each reticular fiber is made up of many transversely striped fibrils 30 nm in diameter. The chemical composition of reticular fibers is not different from that of collagen. Reticular fibers, however, are covered with glycoproteins and proteoglycans, which are stained black by silver impregnation.

F i b r o c y t e s are also always present in connective tissue. They develop from fibroblasts as the latter mature. Fibrocytes are fusiform cells with many processes, a large ellipsoid nucleus and a small amount of

cytoplasm with few organelles. The granular endoplasmic reticulum and Golgi complex are weakly developed. The cytoplasm contains vacuoles, lysosomes and autophagosomes.

Along with cells that synthesize extracellular matrix components loose fibrous connective tissue contains destructive cells, namely, fibroclasts. By shape, development of rough endoplasmic reticulum and Golgi complex fibroclasts resemble fibroblasts. Fibroclasts are rich in lysosomes, which makes them resemble macrophages, and have a high phagocytic and hydrolytic activity.

Loose fibrous connective tissue also contains basophils, adipose and pigment cells, adventitial cells, plasma cells, lymphocytes, all of which perform specific functions.

M a c r o p h a g e s (m a c r o p h a g o c y t e s) are mobile cells. They engulf foreign substances by interacting with lymphoid tissue cells (lymphocytes). Macrophages have various shapes while their sizes vary from 10 to 20 mm. Their cytolemma forms numerous projections. Their nucleus may be round, ovoid or bean-shaped. The cytoplasm contains many lysosomes. Macrophages secrete a large quantity of different enzymes (lysosome enzymes, collagenase, protease, elastase) and other biologically active substances into the extracellular matrix

T i s s u e b a s o p h i l s (m a s t c e l l s) are usually situated around blood vessels. Mast cells have a round or ovoid shape. Their cytoplasm contains different size granules with heparin, hyaluronic acid and chondroitin sulfates. Heparin reduces blood clotting, increases permeability of capillary walls and has an anti-inflammatory effect.

A d i p o s e c e l l s (f a t c e l l s, a d i p o c y t e s) are large (100–120 mm), round shaped and almost completely filled with fat, which accumulates as an energy reserve material. Fat cells are usually situated in groups, forming adipose tissue. When fat is lost from the body the triglycerides in fat cells break down to glycerin and fatty acids, which enter the blood stream and move to other tissues. Adipocytes do not divide or synthesize DNA. New adipocytes can develop from adventitial cells, which are found next to blood capillaries.

A d v e n t i t i a l c e l l s are not highly differentiated and pertain to the fibroblast variety. They lie close to capillaries and are flattened or spindle-shaped. They contain an ovoid nucleus and poorly developed organelles.

P i g m e n t c e l l s (p i g m e n t o c y t e s, m e l a n o c y t e s) have cytoplasmic projections and contain pigment melanin. A large amount of these cells may be found in the iris and epidermis of the skin. Unlike other connective tissue cells, which develop from the middle germinal layer or mesoderm, melanocytes develop from the ectoderm.

Pericytes (perivascular cells, or Ruge cells) are situated outside the endothelium, in the capillary basement membrane. They have cytoplasmic projections, which contact with all endotheliocytes. These projections conduct nervous excitation to endotheliocytes. As a result, endotheliocytes accumulate or lose liquid, which leads to dilation or contraction of the capillary lumen. By structure pericytes resemble fibroblasts, however, their cytoplasm is richer in filaments.

Plasma cells (plasmocytes) and lymphocytes are the «worker» cells of the immune system. They move actively through tissues, including connective tissues, and participate in cellular and humoral immune reactions (see «Organs of the immune system»)

Dense fibrous connective tissue contains well-developed fibrous structures, due to which it plays functions of support and protection. This tissue type contains very few cells. Bundles of collagen fibers prevail in the extracellular matrix. The collagen fibers can interweave with each other in random directions (irregular dense fibrous connective tissue) or lie parallel to one another (regular dense fibrous connective tissue).

Irregular dense fibrous connective tissue forms coverings of muscles, nerves, capsules and trabeculae of many organs. This tissue also forms vessel tunics, eye sclera, periostea, perichondria, joint capsules, the reticular layer of the dermis, heart valves, the pericardium and dura mater. This tissue contains a small quantity of interwoven elastic fibers, which gives it elasticity.

Regular dense fibrous connective tissue forms tendons, ligaments, fasciae and interosseous membranes. Collagen fibers are situated parallel to each other, forming narrow bundles with oblong nuclei. First order collagen fiber bundles join to form thicker bundles of the second order, which are divided by streaks of loose fibrous tissue. Between layers of collagen bundles there are flattened fibrocytes, which synthesize collagen and amorphous extracellular substance.

Elastic connective tissue forms the walls of elastic arteries, elastic cone of the larynx, vocal chords and yellow ligaments. The main elements of this tissue are densely packed elastic fibers, between which there are numerous fibrocytes. Around the elastic fibers there is a thin fibrillar web formed by collagen microfibrils.

Connective tissues with special qualities (adipose, reticular, pigmental) are found only in certain organs and parts of the body and are characterized by special structural features and specific functions.

Adipose tissue performs trophic, storage, thermoregulation and shaping functions. Adipose tissue is divided into two types: white fat, formed by unilocular adipocytes, and brown fat, formed by multilocular

fat cells. Groups of adipocytes make up lobules. These are separated by streaks of loose connective tissue, which contains vessels and nerves. In humans white fat is more common. It covers some organs (e.g. kidneys, lymph nodes, eye ball, etc.), fills cavities of organs, which are not yet functioning (mammary glands), substitutes red marrow in diaphyses of long tubular bones. Most adipose tissue serves for energy storage (subcutaneous fat, epiploon, omentulum, epiploic appendages of the colon). Brown adipose tissue can be found in the organism of a newborn. It is formed by lobules of multilocular adipocytes. The brown color is acquired from the presence of numerous capillaries and an abundance of mitochondria and lysosomes in multilocular adipocytes. The main function of brown adipose tissue in the newborn is heat isolation. In animals it helps support body temperature levels during hibernation.

R e t i c u l a r   c o n n e c t i v e tissue is formed by reticular fibers and reticular cells, which are connected with each other by cytoplasmic projections. Reticular cells and fibers create a web-like framework, loops of which contain lymphocytes, reticular cells, macrophages, plasmocytes and other cells.

P i g m e n t a l   c o n n e c t i v e   t i s s u e is found in the iris and choroidea, the pia mater, skin of external genital organs, nipples and skin surrounding the anus. The pigment cells are connected with each other by cytoplasmic projections and form networks.

Questions for revision and examination

1. Give the classification of connective tissue and name the functions it performs.
2. List the cells and fibers found in connective tissues.
3. Characterize the cells and fibers of connective tissue and name their functions.
4. Describe the morpho-functional characteristics of fibrous connective tissues.
5. Which are the connective tissues with special qualities? Describe their structure and functions.

The Blood

The blood is a variety of connective tissue. It has a liquid extracellular matrix — the blood plasma. Plasma contains the blood cells elements. A human body weighting 70 kg contains on the average 5–5.5 liters of blood (5 – 9% of the total body mass). The function of blood consists in oxygen and nutrient transport to organs and tissues and excretion of products of metabolism.

Plasma is a liquid which remains after removal of all formed elements (cells) from blood. Plasma contains 90–93% various protein substances (albumins, globulins, lipoproteins, fibrinogen), 0.9% salts and 0.1%

glucose. It also contains enzymes, hormones, vitamins and other substances necessary for the organism. Plasma proteins participate in blood clotting processes, create viscosity, help keep blood pressure constant and prevent the settling of erythrocytes. Plasma contains immunoglobulins, which take part in immune reactions of the organism.

Plasma minerals include $NaCl$, KCl, $CaCl_2$, $NaHCO_2$, NaH_2PO_4 and other salts, as well as Na^+, Ca^{2+} and K^+ ions. The consistency of ionic compositions provides for stability of osmotic pressure and liquid volume in blood and cells of the organism.

Formed elements (*cells*) of blood include erythrocytes, leukocytes and thrombocytes (Fig. 14).

E r y t h r o c y t e s (r e d b l o o d c o r p u s c l e s) have no nucleus and are not able to divide. One microliter of blood contains 3.9–5.5 million erythrocytes (an average of 5.0×10^{12} per liter) in men and 3.7–4.9 million (an average of 4.5×10^{12} per liter) in women.

Each erythrocyte has a biconcave shape measuring 7–8 µm in diameter, 1 µm thick in the center and 2–2.5 µm thick at the marginal zone. The surface area of one erythrocyte is about 125 µm. The total surface area for all erythrocytes reaches 3500–3700 m². Erythrocytes have a cytolemm, which is selectively permeable to water, gases and other elements. The cytoplasm contains no organelles. 34% of its volume is taken up by the pigment hemoglobin, the function of which is oxygen and CO_2 transport. Hemoglobin consists of a protein called globin and a non-protein iron-containing group called heme. Hemoglobin carries oxygen from the lungs to organs and tissues and carbon dioxide from tissues and organs to the lungs. When hemoglobin is bound with oxygen it has a bright red color and is called oxyhemoglobin. Oxygen molecules bind to hemoglobin under high partial pressure of oxygen in the lungs. At low partial pressures of oxygen in tissues oxygen is released from oxyhemoglobin and diffuses out of capillaries into surrounding cells and tissues. As it loses oxygen, blood becomes saturated with carbon dioxide, the partial pressure of which is higher in tissues than in blood. Hemoglobin bound with CO_2 is called
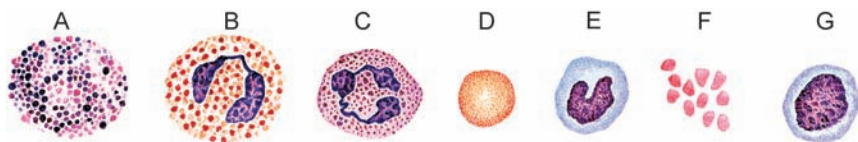
Fig. 14. Blood cells.

A — basophilic granulocyte; B — acidophillic granulocyte(eosinophil); C — segmento-nuclear neutrophilic granulocyte; D — erythrocyte; E — monocyte; F — thrombocyte (platelet); G — lymphocyte.

carbohemoglobin. Carbon dioxide is lost from blood in the lungs, where hemoglobin becomes saturated with oxygen again.

Hemoglobin binds easily with carbon monoxide /CO/, forming carboxihemoglobin. Its affinity to CO is 300 times greater than to oxygen.

L e u k o c y t e s (w h i t e b l o o d c e l l s) are mobile cells, which can have different morphological characteristics. In an average adult one liter of blood contains $3.8{\times}10^9$–$9.0{\times}10^9$ leukocytes. According to an out of date concept, these numbers include lymphocytes, which also develop from stem cells in bone marrow but pertain to the immune system (see «Immune system»). Lymphocytes make up 20 – 35% of total white blood cells (not erythrocytes).

Leukocytes can actively travel through tissue in response to various chemical factors, among which an important role is played by products of metabolism. The shape of leukocytes and their nuclei change during movement.

Depending on the presence or absence of granules in the cytoplasm all leukocytes are divided into granulocytes and agranulocytes. Granulocytes have small granules in their cytoplasm and more or less segmented nuclei. Agranulocytes have no granules and their nucleus is not segmented.

G r a n u l o c y t e s. Granulocytes that can be stained by both acidic and basic dyes are called neutrophils. Those that can be stained only by acidic dyes are called eosinophils; and granulocytes that stain only with basic dyes are called basophils.

N e u t r o p h i l s are round cells 7–9 µm in diameter. They make up 65–75% of total leukocytes (including lymphocytes). They have segmented nuclei, which consist of 2–3 (or more) lobes connected by thin bridges. Some neutrophils have a nucleus shaped like a curved rod (band neutrophils). Young neutrophils contain a bean-shaped nucleus. Cytoplasm in neutrophils contains granules the size of which varies from 0.1 to 0.8 µm.

Neutrophils are mobile cells and have a high phagocytic activity. They engulf bacteria and other particles, which they destroy (digest) with hydrolytic enzymes. Neutrophils live about 8 days. They circulate in the blood during 8–12 hours, after which they migrate into connective tissue where they perform their functions.

E o s i n o p h i l s are about 9–10 µm (up to 14 µm) in diameter. They make up 1–5% of total white blood cells. Their nucleus consists of two (rarely of three) segments, connected with each other by thin bridges. There are juvenile and band forms of eosinophils. Their cytoplasm contains a lot of granules 0.5–1.5 µm in size, which contain hydrolytic enzymes. Eosinophils are not as versatile as neutrophils, however they are also able to migrate from blood into tissue to the site of inflamma-

tion. They can inactivate histamine and inhibit excretion of histamine by mast cells.

B a s o p h i l s have a diameter of 9 mm (11–12 µm on a blood smear). They make up about 0.5–1% of total leukocytes. They have a lobular or spherical nucleus. Their cytoplasm contains granules 0.5–1.2 µm in size. Basophils take part in metabolism of heparin and histamine and can influence the permeability of capillary walls and blood clotting processes.

A g r a n u l o c y t e s. These include monocytes, which make up 6 – 8% of total leukocytes and lymphocytes. They are 9–12 µm in diameter (18–20 µm on a blood smear). The shape of the nucleus may vary (e.g. bean-shape or lobular). The cytoplasm is weakly basophilic and contains small lysosomes and pinocytosis vesicles. Monocytes can act as phagocytes. They circulate in blood for 36–104 hours and then migrate into tissues, where they transform into macrophages.

T h r o m b o c y t e s (platelets) are colorless cells, round or fusiform, 2–3 µm in diameter. One liter of blood contains 200×10^9–300×10^9 thrombocytes. Because of their ability of self-destruction and adherence to each other thrombocytes participate in blood clotting. They have a life span of 5–8 days.

Blood also always contains lymphocytes, which are cells of the immune system. In scientific and educational literature these cells are still classified as agranular leukocytes, which is not quite correct.

L y m p h o c y t e s (see «Blood forming and immune system organs») are found in blood in large quantities (1000–4000 in 1 mm^3). In an average adult the number of lymphocytes reaches 6×10^{12}. Most lymphocytes are constantly circulating in blood and tissues, which allows for efficient immune protection of the organism. All lymphocytes are spherical but differ from each other in size. Their diameter ranges from 8 to 18 µm. Most of the cells are taken up by a round nucleus.

Skeletal tissues

Connective tissue also includes bone and cartilage tissues. The functions of these are support, movement and defense. They also participate in metabolism of mineral substances.

Cartilage

Cartilage tissue forms joint cartilages, vertebral disks, cartilages of the larynx, trachea, bronchi and external nose. Cartilage consists of specialized cells (chondroblasts and chondrocytes) and a dense elastic extra-
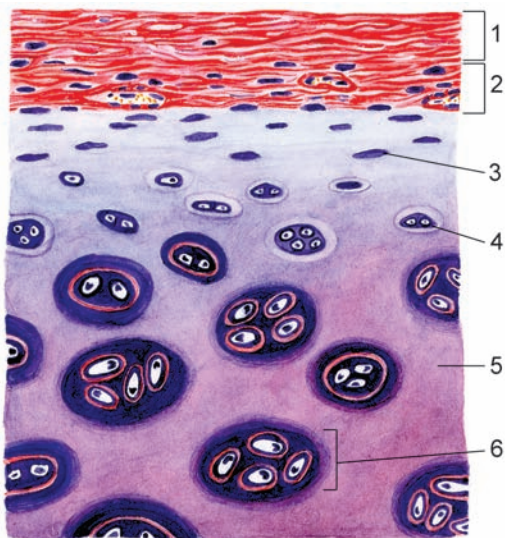
Fig. 15. Structure of the hyaline cartilage, covered by perichondrium
(acc. to A. Ham and D. Kormack).

1 — fibrous layer of perichondrium; 2 — chondrogenic layer of perichondrium; 3 — chondroblast; 4 — chondrocytes within the lacuna; 5 — intercellular substance (cartilage matrix); 6 — chondrocyte aggregate.

cellular matrix (Fig.15). Cartilage contains approximately 70–80% water, 10–15% organic substances and 4–7% salts. About 50–70% of the dry substance in cartilage is collagen. The extracellular substance (matrix), which is produced by cartilage cells, consists of complex compounds, which include proteoglycans, hyaluronic acid and glycosaminoglycans. Proteoglycan molecules bind most of the water in the cartilage.

C h o n d r o b l a s t s are young cells round or ovoid in shape, which are able to divide and synthesize components of the extracellular matrix. Their cytolemm forms a large number of villi. The cytoplasm is rich in RNA, rough and smooth endoplasmic reticulum, Golgi complex, mitochondria, lysosomes and granules of glycogen. The nucleus is rich in chromatin and can have one or two nucleoli.

C h o n d r o c y t e s are mature large cells in oval, rounded or polygonal in shape, cytoplasmic projections and well-developed organelles. They are situated in cavities called lacunae, which are surrounded by extracellular matrix. If a lacuna contains only one cell, it is called primary. More often cells lie in a secondary lacuna in isogenic groups (2–3 cells). Walls of the lacunae are made up of collagen fibers, and aggregates of proteoglycans.

The structural and functional unit of cartilage is a chondron, which includes a cell or group of isogenic cells, extracellular matrix and a lacuna capsule.

Depending on its structure, cartilage is divided into three types: hyaline, fibrocartilage and elastic.

H y a l i n e   c a r t i l a g e has a bluish color. It consists of ground substance and fibers of collagen. Hyaline cartilage forms joint and costal cartilage and most cartilage plates in the larynx.

Fibrocartilage contains a large number of collagen fibers in its ground substance and is highly durable. Elongated cells, which are found between collagen fibers, contain oblong rod-shaped nuclei and have thin bands of basophilic cytoplasm. This type of cartilage forms fibrous rings in vertebral disks, articular disks and menisci, covers the articular surfaces of the temporomandibular and sternoclavicular joints.

Elastic cartilage is resilient and flexible. Besides collagen, its matrix contains a large number of complexly interwoven elastic fibers. Elastic cartilage forms the epiglottis, the cuneiform and corniculate cartilages of the larynx, processus vocalis of the arytenoid cartilage, the outer ear and the cartilaginous part of the auditory tube.

Bone tissue

Bone tissue is characterized by special mechanical properties. It consists of bone cells, bricked up in bone ground substance, which contains collagen fibers and is saturated with inorganic compounds. There are two types of bone cells: osteoblasts and osteocytes (Fig.16). Another category of cells found in bones is osteoclasts, which are not bone cells. They have a monocyte origin and pertain to the system of macrophages.
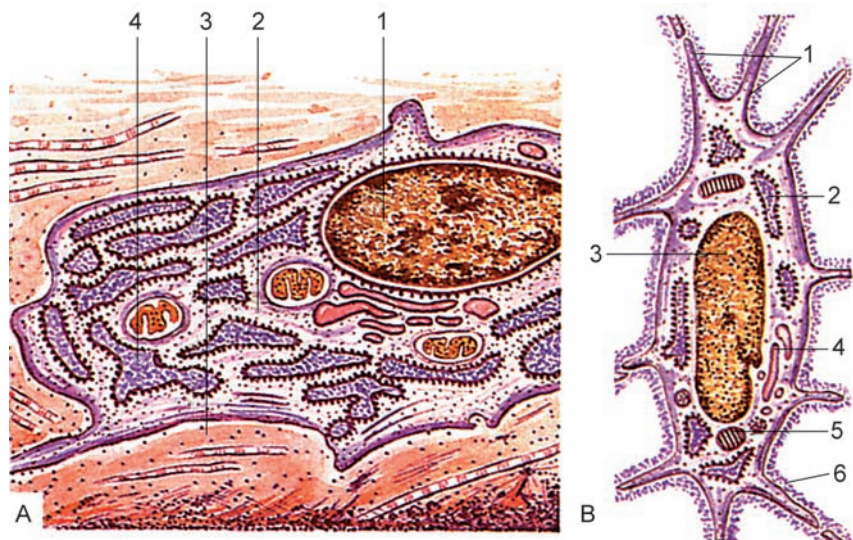

Fig. 16. Osteal cells (acc. to V.G Eliseev and others).

A — structure of the osteoblast: 1 — nucleus; 2 — cytoplasma; 3 — osteocyte; 4 — rough endoplasmic reticulum (is evident). B — structure of osteocyte: 1 — processes of osteocytes; 2 — endoplasmic reticulum; 3 — nucleus; 4 — reticular apparatus; 5 — mitochondrion; 6 — osteoid osteal substance located on margins of osteocyte lacuna.

Osteoblasts are young process bearing cells polygonal in shape. They contain rough endoplasmic reticulum, ribosomes, well-developed Golgi complex and highly basophilic cytoplasm. Osteoblasts are situated in superficial layers of bones. They have a round or oval nucleus, which contains one large nucleolus usually in the peripheral zone. There are microfibrils surrounding the osteoblasts. These cells produce and secrete substances, which form walls of the lacunae, which contain the osteocytes. Spaces between fibers are filled by an amorphous substance, which is an osteoid tissue, or pre-bone, which is later calcified. The organic matrix of bone tissue contains crystals of hydroxyapatite and amorphous calcium phosphate, elements of which pass into bone from the blood through tissue fluid.

O s t e o c y t e s are mature fusiform cells with a large round nucleus, which contains a clearly visible nucleolus, and many cytoplasmic processes. They lie in lacunae, where they are surrounded by a thin layer of so-called bone fluid (tissue fluid). Osteocytes are not in direct contact with the calcified matrix. Their long cytoplasmic processes lie inside bone canaliculi. They are also separated from the calcified matrix by space containing tissue fluid, which feeds the osteocytes. The distance between an osteocyte and the nearest capillary does not exceed 100 – 200 mm.

O s t e o c l a s t s are large multinuclear cells of size 190 mm. The have a monocyte origin and are able to destroy bone and cartilage and reabsorb bone tissue during its physiological and reparative regeneration. Their cytoplasm contains a large number of mitochondria, elements of granular endoplasmic reticulum and Golgi complex, free ribosomes and lysosomes.

O s t e o c l a s t s have numerous cytoplasmic projections, usually found on the surface, that is, facing the deteriorating bone. This brush border increases the surface area of the osteoclast in contact with the bone. The projections are covered with microvilli, spaces between which contain hydroxyapatite crystals. These crystals can be found inside osteoclasts in phagolysosomes, where they are dissolved.

Bone tissue can be subdivided into two varieties: reticulofibrous and lamellar. R e t i c u l o f i b r o u s bone tissue is found in zones where tendons attach to bones and in sutures of the skull after their fusion. This type of bone contains thick bundles of collagen, spaces between which are filled with an amorphous substance. Reticulofibrous tissue is covered on the outside by periosteum.

L a m e l l a r   b o n e   t i s s u e is formed by bone lamellae 4 – 20 mm thick, which consist of osteocytes and fibrous ground substance. In each lamella collagen fibers lie parallel to each other. Fibers in neighboring lamella are oriented differently, which provides for high durability of the bone.

1. What is blood plasma? What are its functions?
2. Name the cell elements of blood and describe the morpho-functional characteristics of each.
3. Describe the structure and functions of cartilage tissue.
4. Describe the structural characteristics of hyaline, fibrocartilage and elastic cartilage.
5. Recall and describe the structural characteristics and functions of osteocytes, osteoblasts and osteoclasts.
6. What are the differences between lamellar and reticulofibrous bone tissue?

MUSCLE TISSUE

Muscle tissue includes skeletal, smooth and cardiac muscles, all of which have different embryological derivation and structure. A common characteristic of these tissues is their ability to contract or change their length. The human organism also contains muscle tissue of ectodermal derivation (myoepithelial cells of glands and myocytes of the iris).

Skeletal (*striated*) *muscle tissue* is made up of muscle fibers 4 cm or more in length and 0.1 mm thick. Each fiber consists of a myosymplast and myosatellitocytes, covered with a common membrane called sarcolemma (Fig. 17).

The sarcolemma consists of a basement membrane with interwoven collagen and reticular fibers. The myosymplast, which lies beneath the sarcolemma is also called the sarcoplasm. It contains a large number of ellipsoid nuclei (up to 100), myofibrils and cytoplasm. The sarcoplasm is
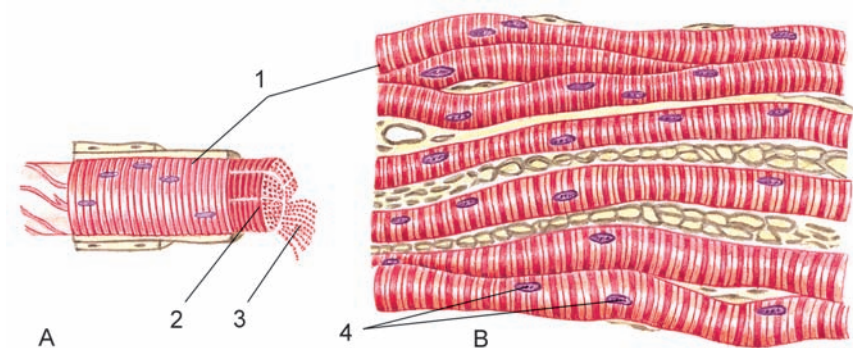

Fig. 17. Striated (skeletal) muscle tissue.

A — structure of muscle fibre; B — muscle fibers; 1 — myofiber; 2 — sarcolemma; 3 — myofibrils; 4 — nucleus.
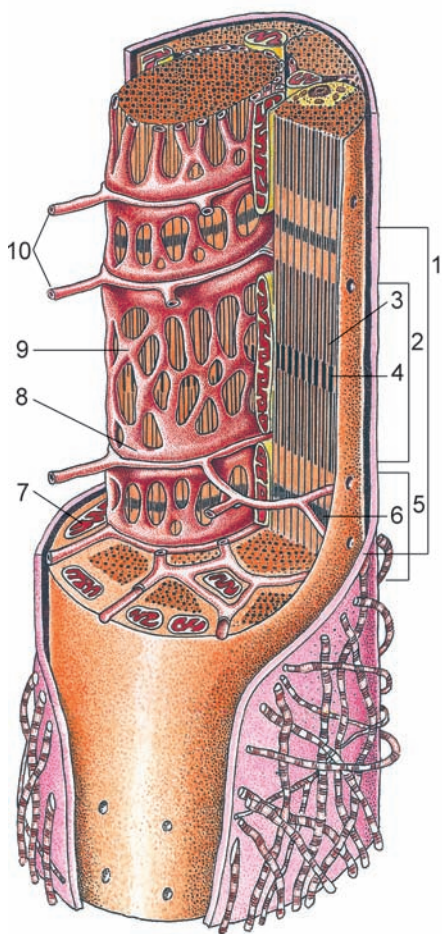
Fig. 18. Structure of the two myofibrils of myofiber (acc. to V.G.Eliseev and co-authers).

1 — sarcomer; 2 — A-band (A — disk); 3 — Pale zone (H — band); 4 — M-band (mesophragma) within disk center of H-band; 5 — I — band (I — disk); 6 — telophragma within the center of I — disk; 7 — mitochondrium; 8 — end cistern; 9 — sarcoplasmic reticulum; 10 — transverse tubules.

rich in granular endoplasmic reticulum. A considerable part of the muscle fiber is occupied by myofibrils. Between the muscle fibers there are many granules of glycogen and mitochondria with well-developed cristae. The sarcoplasm contains a lot of the protein myoglobin, which can bind with oxygen like hemoglobin. Depending on thickness and myoglobin content, striated muscle fibers are divided into red and white types. Red fibers are rich in sarcoplasm, myoglobin and mitochondria but contain fewer myofibrils. These fibers contract slowly and can remain in a contracted /working/ condition for a long time. White muscle fibers contain little sarcoplasm and myoglobin and few mitochondria, but have a lot of myofibrils. White fibers contract faster than red fibers, but tire quickly. Combinations of slow («red») and fast («white») muscle fibers provides quickness of muscle reaction (contraction) and long lasting work capability.

The main part of the sarcoplasm is made up of myofibrils (Fig. 18). Each myofibril consists of interchanging segments of dark anisotropic A bands and light isotropic I bands. In the middle of each band there is a light strip called the H zone. The middle of the H zone is marked by the M line, or mesophragm, and in the middle of the I band is the Z line, or the so-called telophragm. The alternating of the light and dark bands in neighboring myofibrils creates the

striated appearance. The dark bands are formed by thick myosin strands 10–15 nm in diameter. These strands are made up of a high-molecular protein myosin. The light bands consist of thin actin filaments 5–8 nm in diameter and about 1 mm in length. These thin filaments are formed by a low-molecular protein actin, and two other low-molecular proteins troponin and tropomyosin.

The section between two telophragms (Z lines) is called the sarcomere and is considered to be the functional unit of the myofibril. A sarcomere is about 2.5 µm long and includes a dark A band and the adjoining half of a light I band at each side. Thin actin filaments are situated in the intervals between the heavy myosin filaments. During contractions of the muscle the actin

Fig. 19. Structure of the smooth nonstriated muscle tissue (acc. to I.V. Almasov and L.S. Sutulov).

1 — myocyte; 2 — myofibrils within sarcoplasma; 3 — nucleus of myocyte; 4 — sarcolemma; 5 — endomysium; 6 — nerve; 7 — blood vessel.

and myosin filaments slide towards each other; during muscle relaxation they move in opposite directions.

On borders between A and I bands the sarcolemma of the muscle fiber invaginates, forming transverse tubules (T tubules). These play an important role in fast conduction of the action potential to each myofibril. The action potential spreads along T tubules, passes onto the sarcoplasmic reticulum and between myofibrils.

Myosatellitocytes are situated directly beneath the sarcolemma. These are flattened cells with large nuclei. Each myosatellitocyte has a centrosome and a small number of organelles and lacks myofibrils. Myosatellitocytes are precursor cells of striated (skeletal) muscle tissue. They are able to synthesize DNA and undergo mitosis.
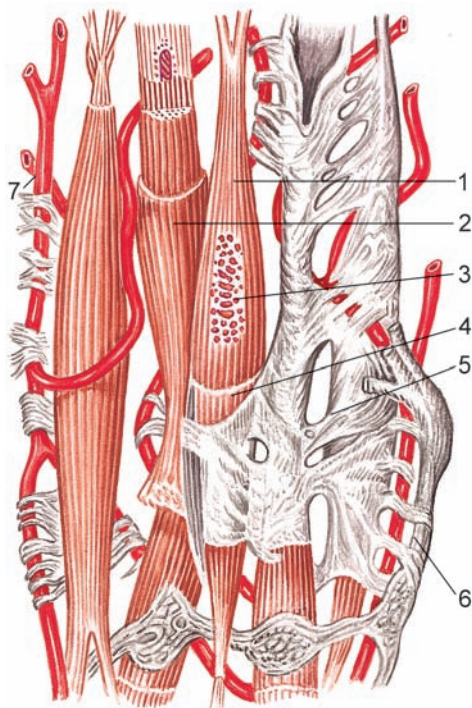
Smooth (*non-striated*) *muscle tissue* consists of muscle cells called myocytes, which are found in the walls of circulatory and lymph vessels and hollow organs, forming their contractile apparatus. Smooth myocytes are fusiform cells 20–500 μm long and 5–15 μm thick (Fig 19). There is no striation in these cells. Myocytes are situated in groups with their pointed ends in between two neighboring cells. Each smooth myocyte has a basement membrane, which is absent at sites of cell junctions. These cells contain elongated rod-shaped nuclei, which can reach 10–25 μm in length and during contraction acquire a corkscrew shape. Adjoining the plasma membrane from within are dense (adhesive) corpuscles.

Smooth myocytes contain thin and thick myofilaments. During contraction actin and myosin filaments move towards each other and the myocyte shortens. Nerve impulses are passed from one myocyte to another through cell junctions at a speed of approximately 8–10 cm/s. Smooth myocytes contract considerably slower (by 100–1000 times) than striated muscle fibers (Fig.19). Smooth muscles carry out prolonged tonic contractions and relatively slow movements.

Cardiac muscle tissue differs by structure and functions from skeletal muscles. It consists of cardiac myocytes (cardiomyocytes), which form interconnected complexes. Cardiac muscle resembles skeletal muscle tissue by its microscopic structure (transverse striation), but it contracts involuntarily like smooth muscle tissue (Fig.20). Cardiomyocytes have an
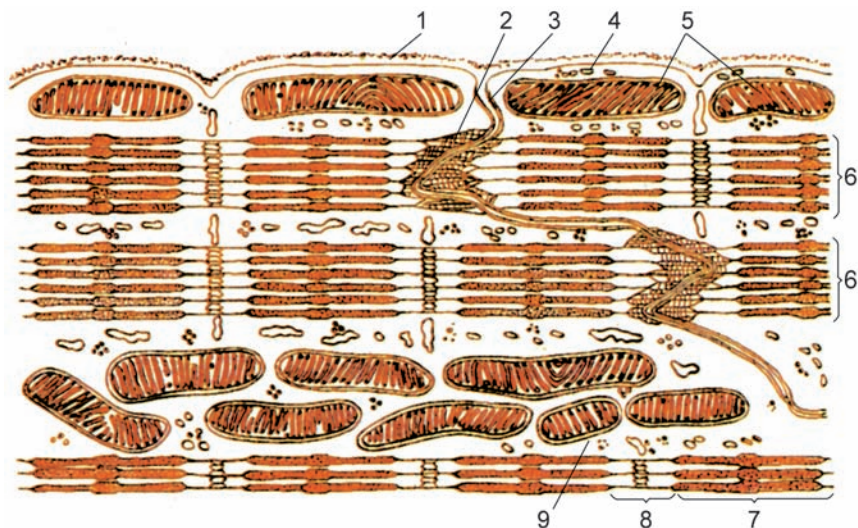

Fig. 20. Structure of cardiomyocyte (acc. to V.G.Eliseev).

1 — basal membrane; 2 — ending of myofibrils on cardiomyocyte cell membrane; 3 — intercallated disc (between cardiomyocytes); 4 — sarcoplasmic reticulum; 5 — mitochondrion (sarcosome); 6 — myofibrils; 7-A — band (anisotropic); 8- I — band (isotropic); 9 — sarcoplasma.

irregular cylindrical shape; cells are 100–150 mm long and 10–20 mm in diameter. Each cardiomyocyte contains 1 or 2 elongated oval nuclei, which lie in the center of the cell and are surrounded by longitudinally positioned myofibrils. Between neighboring cardiomyocytes there are specialized contacts in the form of intercalated disks, which actively take part in passing excitation from one cell to another. The structure of myofibrils in cardiomyocytes is analogous to that in skeletal muscles. Beneath the cytolemma and between mitochondria there are granules of glycogen and elements of smooth endoplasmic reticulum. Cardiomyocytes contain many large mitochondria with well-developed cristae, which are situated in groups between myofibrils. The cytolemma of cardiomyocytes also forms T tubules, near which there are accumulations of smooth endoplasmic reticulum cisterns.

Questions for revision and examination

1. Describe the structure of skeletal (striated) muscle tissue.
2. What are the red and white muscle fibers? What are their morpho-functional differences?
3. Describe the structure of a sarcomere and its location in a muscle fiber.
4. What is smooth /non-striated/ muscle tissue? Describe its structure and functions.
5. Describe the structure and functions of cardiomyocytes /cardiac muscle tissue/.

NERVOUS TISSUE

Nervous tissue is the main structural element of organs of the nervous system, namely, the brains and spinal chord, ganglia, nerves and nerve endings. Nervous tissue consists of nerve cells (neurocytes or neurons) and accessory neuroglial cells, which are anatomically and functionally associated with them.

N e u r o c y t e s (n e u r o n s) and their processes are able to perceive excitation, become excited, produce, store and pass information encoded in electrical or chemical signals (nerve impulses).

Each neuron has a cell body and processes with endings (Fig. 21). Nerve cells are covered with a cytolemma, which is able to conduct excitation and provide for cell metabolism. The body of a nerve cell contains a nucleus and the cytoplasm surrounding it (perikaryon). The cytoplasm of neurons contains certain characteristic structures—neurofibrils and a chromatophilic substance (Nissl substance) the presence of which (granular endoplasmic reticulum) indicates high levels of protein synthesis. Neurofibrils are bundles of microtubules and neurofilaments, which participate in transport of substances. The diameter of neuron cells bodies rang-

es from 4–5 to 135 mm. The shape of cell bodies also varies — it may be round, oval or pyramidal. Nerve cells have different length cytoplasmic processes, which are divided into two types. There are one or several branched out processes called dendrites, which carry nerve impulses to the neuron body. In majority of cells they are approximately 0.2 mm long. The cytoplasm in dendrites contains elongated mitochondria and a small number of cisterns of smooth endoplasmic reticulum. There is only one process, usually it is long, which carries nerve impulses away from the cell body — the axon, or neurite.

The axon starts from the neuron body and ends with a bunch of terminal branches, which form synapses. The surface of the axon cytolemme (axolemma) is smooth. Axons contain thin elongated mitochondria, a large amount of neurotubules and neurofilaments, vesicles and tubes of smooth endoplasmic reticulum. Nerve cells are dynamically polarized, meaning they are able to conduct nerve impulses only in one direction—from dendrites to axon.
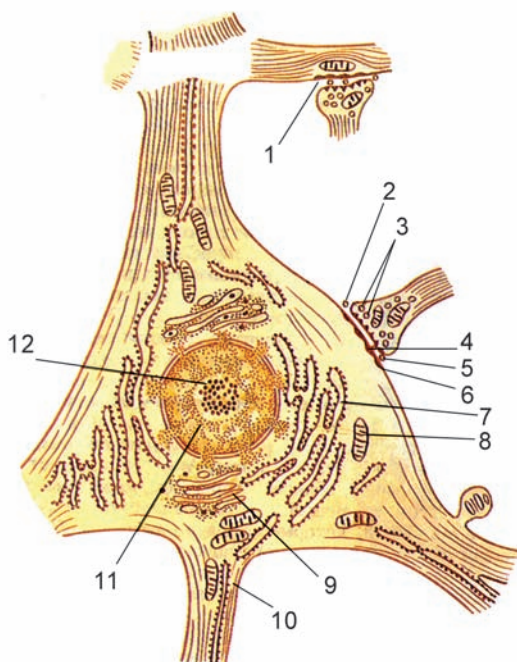

Fig. 21. Ultramicroscopic structure of nerve cell.

1 — axodendritic synapse; 2 — axosomatic synapse; 3 — presynaptic vesicules; 4 — presynaptic membrane; 5 — synaptic gap; 6 — postsynaptic membrane; 7 — endoplasmic reticulum; 8 — mitochondrion; 9 — golgi complex; 10 — neurofibrils; 11 — nucleus; 12 — nucleolus.

Nerve fibers are neuron processes (dendrites, axons) covered with sheaths. In a fiber the neuron process acts as an axial cylinder, while neurolemmocytes (Schwann cells), which pertain to neuroglia, wrap around it forming the sheath, or neurilemma. Depending on the structure of the neurilemma, nerve fibers are divided into myelinated and unmyelinated.

Unmyelinated nerve fibers are found mainly in autonomic neurons. These nerve fibers have thin sheaths, their axial cylinder presses into a deep groove formed by a Schwann cell (Fig.22). The membrane of the neurolemmocyte, which covers the process with two layers, is called the mesaxon. The Schwann cells, which form the nerve fiber sheath, are situated in a line, one after another. Beneath the Schwann cells there is a narrow space (10–15 nm) with tissue fluid, which participates in conduction of nerve impulses.

Fig. 22. Structure of nonmyelinated nerve fiber (acc. to V.G. Eliseev and others).

A — longitudinal section; B — transverse section; 1 — axial cylinders; 2 — axolemma; 3 — mesaxon; 4 — Schwann (Neurolemnal) sheath; 5 — cytoplasma of neurolemmocyte; 6 — nucleus of neurolemmocyte (dot-line shows flat of transverse section); 7 — contact of two neurolemmocytes.

Myelinated nerve fibers are about 20 mm in thickness (Fig.23). They contain the relatively thick axon as the axial cylinder. Around the axon there is a sheath, which consists of two layers. The inside layer is the thicker myelin sheath. On the outside is a thin layer formed by Schwann cells. Dendrites do not have myelin sheaths. Each Schwann cell wraps only a small area of the axon. The underlying myelin layer, which is made up of lipids, is also discontinuous. Thus, every 0.3–1.5 mm there are gaps called neurofibral nodes (nodes of Ranvier), in which there is no myelin layer (Fig.24). In these areas neighboring Schwann cells approach the axon directly with their edges. The basement membrane, which covers the Schwann

Fig. 23. Sequenced stages (A, B, C) of forming of myelinated nerve fiber
(acc. to V.G.Eliseev and others).

1 — contact of axolemma and Schwann (Neurolemnal) sheath; 2 — intercellular gap (fissure); 3 — axolemma and Schwann (neurolemnal) sheath; 4 — cytoplasma of neurolemmocyte; 5 — mesaxon.

cells, is continuous and crosses over the nodes of Ranvier without interrupting. These nodes are areas of penetration for sodium ions during nerve impulse depolarization /electric current/. Depolarization in nodes of Ranvier allows for fast conduction of nerve impulses along myelinated nerve fibers. Impulses are conducted along these fibers in saltatory jumps from one node of Ranvier to the next. In unmyelinated nerve fibers depolarization takes place in all parts, which is why impulses are conducted slower. Thus, the speed of conduction along unmyelinated fibers is 1–2 m/s and along myelinated ones is 5–120 m/s.

Classification of neurons. Depending on the number of processes there are u n i p o l a r (have one process) and b i p o l a r (two processes) neurons (Fig.25). M u l t i p o l a r neurons have many processes. There are also pseudo-unipolar neurons, which pertain to bipolar neurons. These neurons have
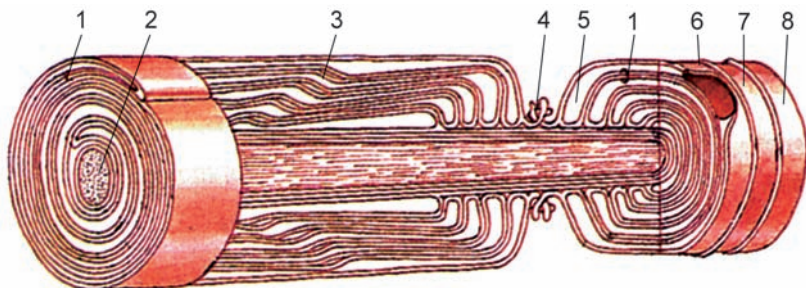
Fig. 24. Structure of myelinated nerve fiber and neurofiber node of Ranvier
(acc. to V.G. Eliseev and others).

1 — mesaxon; 2 — axial cylinder; 3 — myelin incisure; 4 — neurofiber node; 5 — cytoplasma of neurolemmocyte; 6 — nucleus of neurolemmocyte; 7 — neurolemma; 8 — endoneurium.

one short process extending from the cell body, which then divides into an axon and a dendrite. The number of dendrites and the extent of their branching depend on the location and function of the neuron. Pseudounipolar neurons have a round body and slightly branching processes. Multipolar neurons have an irregular cell body shape, many slightly-branching dendrites extending into different directions and a long axon.
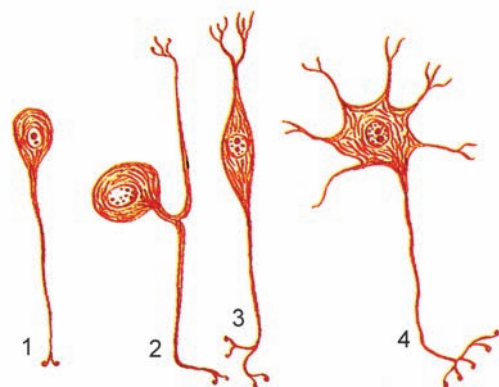
Fig. 25. Types of neurons (acc. to V.G.Eliseev and others).

1 — unipolar neuron; 2 — pseudounipolar neuron; 3 — bipolar neuron; 4 — multipolar neuron.

The large pyramidal neurons of the cerebral cortex have a triangular shape and a large number of short dendrites. Their axon extends from the base of the pyramidal cell.

Both dendrites and axons end with nerve endings. Dendrite nerve endings are sensitive, while the axon ending is effectorial.

According to their function, nerve cells are divided into sensory, effectorial and associative cells.

Sensory (receptor) neurons are able to perceive various stimulations with their endings. Impulses generated in the nerve endings (receptors) of these cells are conducted to the cerebellum. Because of this sensory neurons are also called afferent. Effectorial nerve cells are also called efferent. Associated (interneurons, relay neurons) conduct impulses from afferent to efferent neurons. There are also neurons, which can produce secretion, these are called neurosecretory. Their secretion (neurosecretion) is excreted in the form of granules and transported by blood. Neurosecretion is a way of interaction of the nervous and cardiovascular (humoral) systems.

Depending on their location receptors are divided into exteroceptors, interoceptors and proprioceptors. Exteroceptors perceive influences from the environment. They are situated in the external teguments of the body— the skin, mucosae and sensory organs. Interoceptors sense stimuli, which are produced by changes in chemical composition of the internal environment (chemoreceptors) and pressure inside tissues and organs (baroreceptors, mechanoreceptors). Proprioceptors perceive stimuli in muscles, tendons, ligaments, fasciae and joint capsules.
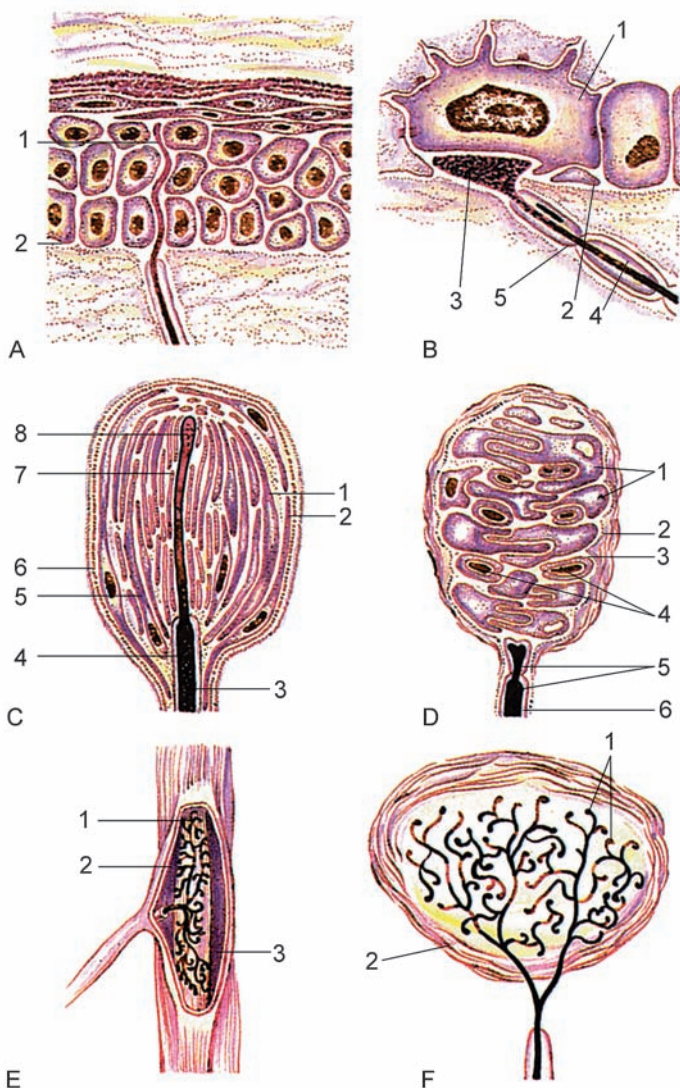
Fig. 26. Structure of various receptors (acc. to A.Ham and D.Kormack).

A — free nerve ending: 1 — nerve ending; 2 — border between dermis and epidermis. B — free (Merckel's) ending: 1 — modified epidermal cell (Merckel's cell); 2 — basal membrane; 3 — end disk of afferent fiber; 4 — myeline; 5 — neurolemmocyte. C — Pacinian corpuscle: 1 — subcapsulr space; 2 — capsule; 3 — myelin; 4 — neurolemmocyte; 5 — external bulbus; 6 — basal membrane; 7 — internal bulbus; 8 — terminal process of afferent fiber. D — Meissner's lamillar corpuscle: 1 — flatterned neurolemmocytes; 2 — capsule; 3 — basal membrane; 4 — spiral terminals of afferent fiber; 5 — neurolemmocytes; 6 — myelin. E — Ruffini's tactile corpuscle: 1 — bundles of collagen fibers within body's nucleus; 2 — terminal branches of afferent fiber; 3 — capsule. F — terminal variosity (Krause's corpuscle): 1 — terminal branches of afferent fiber; 2 — capsule.

Based on their function there are thermoreceptors, which perceive changes in temperature, and mechanoreceptors, which sense mechanical influences (touch, pressure on the skin). There are also nociceptors, which are able to perceive pain stimuli.

Nerve ending can also be divided into free (naked) nerve endings and encapsulated ending, which are covered by a tunic (capsule) made up of neuroglia cells or connective tissue fibers (Fig. 26).

F r e e   n e r v e   e n d i n g s are found in the skin, where they branch out between epitheliocytes. Such endings are also found in mucosae and cornea of the eye. Terminal free nerve endings can perceive pain, heat and coldness.

E n c a p s u l a t e d   n e r v e   e n d i n g s are covered by a connective tissue capsule. This group of endings includes tactile (Meissner's) corpuscles, lamellated (Pacinian) corpuscles, bulbous (Golgi-Mazzoni) corpuscles and corpuscles of Ruffini. All these nerve endings are mechanoreceptors. This group also includes bulbous corpuscles of Krause, which are thought to be thermoreceptors.

L a m e l l a t e d   (V a t e r - P a c i n i a n)   c o r p u s c l e s are the largest among encapsulated endings. They reach 3 – 4 mm in length and 2 mm in thickness. They are found in connective tissue of internal organs, dermis and subcutaneous tissue. On the outside the corpuscle is covered with a connective tissue capsule, which has a lamellated structure and is rich in capillaries.

T a c t i l e (M e i s s n e r ' s)   c o r p u s c l e s are small (50–160 μm long and about 60 μm wide). They are especially concentrated in the papillary dermal layer of the skin on fingers, lips, edges of eyelids and external genital organs. Their capsule is formed by several layers of epithelioid cells. Meissner's corpuscles are mechanoreceptors, which perceive touch and pressure applied to the skin.

C o r p u s c l e s   o f   R u f f i n i are spindle-shaped receptors, found in the skin on fingers, hands and feet, in joint capsules and walls of blood vessels. The corpuscles are covered with thin capsules, which are formed by perineurial cells. Corpuscles of Ruffini are mechanoreceptors; they are thought to perceive heat and are proprioceptors.

K r a u s e ' s   c o r p u s c l e s (bulbous corpuscles) are spherically shaped and are found in skin, eye conjunctiva and mucosa of the mouth. The corpuscles have a thick connective tissue capsule. Krause's corpuscles are cold receptors and, possibly, mechanoreceptors.

The papillary dermis in the skin of glans penis and clitoris contains many of the so-called genital corpuscles, which are similar to bulbous corpuscles. These are mechanoreceptors.
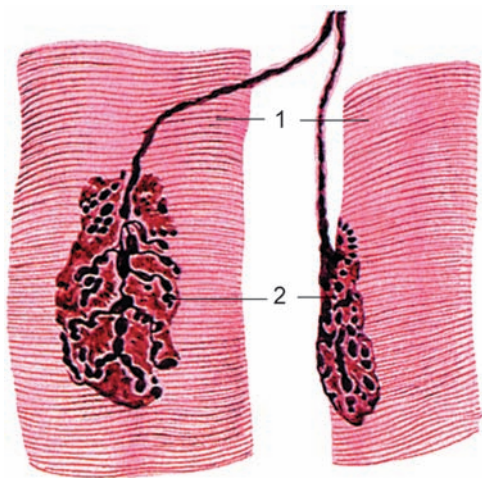
Fig. 27. Neuro-muscular terminal.
1 — myofiber; 2 — motor patch.

Proprioceptors perceive muscle contractions, stretching of tendons, joint capsules and muscle strength, necessary for movement or keeping body parts in a certain position. This group includes neuromuscular spindles and tendon organs.

Tendon organs are located in places of transition between muscles and tendons. They take form of bundles of tendon (collagen) fibers, are connected with muscle fibers and surrounded by a connective tissue capsule.

Neuromuscular spindles are large, 3–5 mm long and 0.5 mm thick, and are covered with a connective tissue capsule. Such a capsule contains up to 10–12 short thin striated muscle fibers of various structures.

Muscles also contain effectorial neuromuscular endings, which are found on each muscle fiber (Fig. 27). These are thickened endings covered by Schwann cells and their basement membrane, which transcends into the basement membrane of the muscle fibers. The axolemma of each nerve ending touches the sarcolemma of one muscle fiber, as if pressing it inwards. A gap between the nerve ending and the muscle fiber is filled with an amorphous substance, which, as in a synapse, contains acetylcholinesterase.

Effectoral nerve endings of smooth muscles form dilations, which contain mitochondria and synaptic vesicles, containing noradrenaline and dopamine. The majority of nerve endings are in contact with the basement membrane of myocytes, while some endings perforate it. In contacts between nerve fibers and smooth muscle cells the axolemme is separated from the cytolemme by a 10 nm gap.

Neurons perceive, conduct and transmit electrical signals (nerve impulses) to other nerve cells or working organs (muscles, glands, etc.).

Nerve impulses are transmitted between neurons through specialized intercellular contacts called synapses. Synapses can be divided into axosomatic, axodendritic and axoaxonic. Axosomatic synapses are formed between the nerve ending of one neuron and the cell body of another. Axodendritic synapses are contacts between axons of one cell and dendrites of an-

other. Axoaxonic contacts are synapses between axons of two neighboring cells. Formation of these contacts creates chains of neurons. Nerve impulses are transmitted along neuron chains with the aid of bioactive substances called neurotransmitters. These neurotransmitters include noradrenalin, acetycholine, monoamines (adrenalin, serotonin, etc.), as well as some neuropeptides (enkephalins, neurotensin, somatostatin, etc.).

Each synapse has presynaptic and postsynaptic parts, which are separated from each other by a 20–30 nm gap. When a nerve impulse reaches the presynaptic part it causes Ca^{2+} channels to open. The increase in Ca^{2+} concentration results in the release of neurotransmitters, which are stored in synaptic vesicles, into the synapse. The neurotransmitter binds to receptors on the postsynaptic membrane. This causes a postsynaptic potential to generate in the form of a nerve impulse. The magnitude of the postsynaptic potential is directly proportional to the quantity of excreted neurotransmitter.

Also part of the nervous system is **neuroglia cells**, which carry out supporting, trophic, defensive, isolating and secretory functions. Neuroglia is divided into glia of the nervous system (ependymocytes, astrocytes, oligodendrocytes and microglia) and glia of the peripheral nervous system (neurolemmocytes) (Fig. 28).
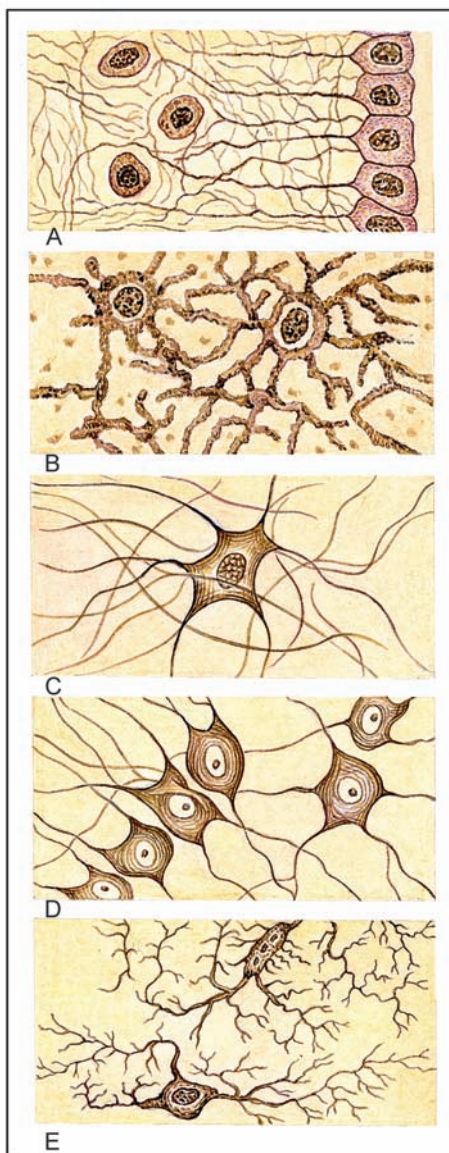
Fig. 28. Neuroglia (acc. to V.G.Eliseev and others).

A — ependimal cell; B — protoplasmic astrocytes; C — fibrous astrocytes; D — oligodendrocytes; E — microglial cell.

E p e n d y m o c y t e s line on the inside the ventricles of the brain and the cerebrospinal canal. These cells have a cuboidal or prismatic shape; they lie in a single layer and have microvilli. Their basal surface is in contact with blood capillaries. Ependymocytes participate in the formation of cerebrospinal fluid and carry out functions of support and demarcation.

A s t r o c y t e s are the main connective element of the central nervous system. There are protoplasmic and fibrous astrocytes.

Fibrous astrocytes are multiprocessed cells, which are predominant in the white matter of the central nervous system. Their processes are located between nerve fibers. Some of the processes reach blood capillaries. Protoplasmic astrocytes have a stellar shape and long cytoplasmic protrusions stretching in all directions from the cell body. These protrusions provide support for neuron processes and create a reticulum in which neuron cell bodies lie. Astrocyte processes, which reach the brain surface, connect with each other to form a continuous boundary membrane. This glial membrane creates specific microsurroundings for neurons.

O l i g o d e n d r o c y t e s are small (6–8 mm) ovoid cell with processes and a large nucleus. They are situated around neurons and their processes. Oligocytes, which form sheaths of neuron processes in the peripheral nervous system, are called neurolemmocytes, or Schwann cells.

M i c r o g l i a (O r t e g's c e l l s) is made up of small cells of an undefined shape. There are numerous processes of various sizes and shrublike appearance stretching from cell bodies. Microglia cells are mobile and have a phagocytic ability.

Questions for revision and examination

1. Describe the structure and functions of a nerve cell and nerve fibers /myelinated and unmyelinated/.
2. Give the classification of nerve endings, describe their morphological and functional characteristics.
3. What are synapses, what features are used to classify them?
4. Describe the structure of a synapse and the mechanism of nerve impulse transmission though it.
5. Give the classification of neuroglia, describe its structure and the functions of its different components.

MAIN STAGES OF DEVELOPMENT IN ONTOGENESIS

Each human being possesses individual traits of outer appearance and internal organ structure, which are determined by hereditary factors and influences of the environment.

Individual development of a human organism lasts throughout all periods of life — from conception until death. Ontogenesis of a person is divided into the intrauterine (prenatal) and the «after birth» (postnatal) periods. During the intrauterine period, which lasts from conception until birth, the embryo develops inside the mothers womb. In the course of the first 8 weeks of embryogenesis the main processes of organ and body part formation take place. This period is called the embryonic period, and the future human organism — the embryo. Starting on the 9th week, when main external features have begun to designate, the organism enters the fetal period of development and begins to be called a fetus.

After conception, which usually takes place in a uterine tube, fused sex cells (ovum and spermatozoid) form a unicellular 'germ' called a zygote, which possesses all the attributes of both sex cells. From this moment begins the development of a new /daughter/ organism.

During its first week of development the zygote divides into daughter cells (cleavage stage). In the first 3–4 days the zygote is simultaneously dividing and moving along the uterine tube towards the uterus. As a result of its divisions the zygote transforms into a multicellular vesicle (blastula) with a cavity inside (Fig.29). The walls of this vesicle are made up partially of larger and partially of smaller cells. The smaller cells form the outside layer of the blastula wall and is called the trophoblast. Later on the trophoblast cells form the outer layer of the extraembryonic membranes. The larger cells (blastomeres) form a cell mass called an embryoblast, which is situated to the inside of the trophoblast. This inner cells mass /embryoblast/ later develops into the embryo. Between the trophoblast and the embryoblast accumulates a small amount of fluid.

By the end of the 1st week of development (6–7th day of pregnancy) the embryo implants into the mucosa of the uterus. For this to happen, cells of the trophoblast secrete an enzyme, which loosens the surface layer of the mucosa, which at this time is already prepared for the implantation. At the moment of ovulation (excretion of the ovum from the ovary) the mucosa inside the uterus is thickened (up to 8 mm) and has uterine
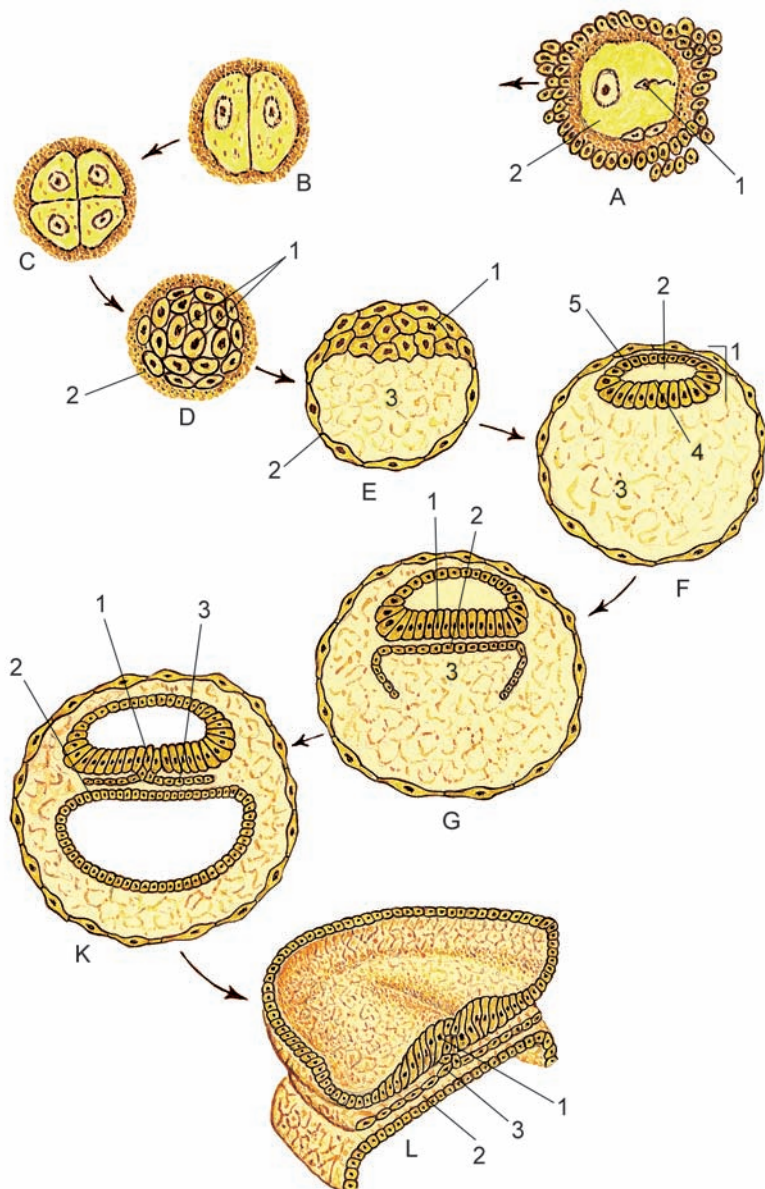
Fig. 29. Cleavage of a zygote and formation of germinal layers (acc. to R. Kristic, modified, 1984).

A — insemination: 1 — spermatozoid; 2-oocyte; B,C – cleavage of zygote; D — moruloblast: 1 — embryoblast; 2— trophoblast; E — blastocyst: 1 — embryoblast; 2 — trophoblast; 3 — amniotic cavity. F — blastocyst: 1 — embryoblast; 2 — amniotic cavity; 3 — blastocele; 4 — embryonic entoderm; 5 — amniotic epithelium. G, K, L: 1 — ectoderm; 2 — entoderm; 3 — mesoderm.

glands and vessels proliferating in it. The trophoblast forms numerous protrusions called villi, which increase its contact surface area with the mucosa. The trophoblast transforms into an extraembryonic nourishing membrane called the chorion. At first there are chorionic villi all around the blastula, but later the villi remain only on the side in contact with the uterine wall. Out of the chorion and the adjoining mucosa a new organ called the placenta («baby's place») is formed. The placenta is the organ, which connects the mother's organism with the embryo, providing it with nourishment.

The second week of embryonic development is a stage when cells of the embryoblast divide into two layers (discs), which form into two vesicles (Fig. 30).

The outside cell layer, which adjoins the trophoblast, forms the ectoblastic vesicle, which becomes filled with amniotic fluid. The inside layer
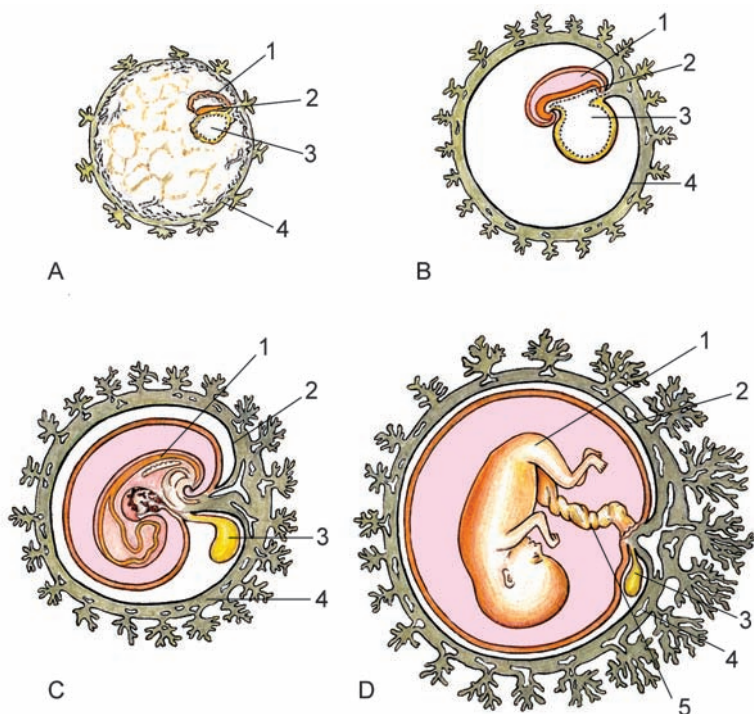
Fig. 30. Positioning of a human embryo and embryonic tunics during different stages of development.

A — embryo weeks 2—3; B — embryo weeks 4: 1 — amniotic cavity; 2 — embryo body; 3 — yolk sac; 4 — trophoblast; C — embryo weeks 6; D — embryo months 4—5: 1 — body; 2 — amnion; 3 — yolk sac; 4 — chorion; 5 — umbilical cord.

forms an endoblastic vesicle (yolk sac). The embryonic disk («body») is situated where the amniotic cavity connects to the yolk sac. During this stage the embryo has the shape of a bilaminar disk made up of an external (ectoderm) and internal (endoderm) embryonic sheets. The ectoderm faces the amniotic cavity, and the endoderm adjoins the yolk sac. At this stage it is possible to define surfaces of the embryo. The dorsal surface adjoins the amniotic cavity and the ventral surface contacts the yolk sac. The trophoblast cavity around the amniotic and yolk vesicles is loosely filled with cells of extraembryonic mesenchyme. By the end of the 2nd week the length of the embryo is approximately 1.5 mm. During this stage the bilaminar embryonic disk thickens in its posterior (caudal) part. This is where the axial organs (chorda, neural tube) will later develop.

During the third week of development the formation of the three-layered embryo takes place. Some cells of the ectoderm migrate toward its posterior end, forming a cell cord called the primitive streak. In the anterior (head) section cells of the primitive streak grow and divide faster, which results in the formation of the primary nodule (Hensel's nodule). The primitive streak determines the bilateral symmetry of the body. The location of the primary nodule marks the cranial (head) end of the embryo.

Later on, the cells of the primitive streak and primary nodule grow in between the ectoderm and endoderm. This creates the middle embryonic layer — the mesoderm. Cells of the mesoderm, which stay between the two layers of the embryonic disk are called intraembryonic mesoderm; cells that have migrated outside the disc make up the extraembryonic mesoderm.

Part of the mesoderm cells within the primary nodule grows particularly actively, forming the cranial (chordal) process. This process penetrates between the external and internal layers up to the caudal end, forming the chorda (notochord). The cranial part of the embryo grows faster than the caudal end. At the end of the 3rd week a longitudinal strip of actively dividing cells (neural plate) appears within the ectoderm in front of the primary nodule. This plate then forms a longitudinal fold — the neural sulcus. As the sulcus deepens, its edges thicken, converge and grow together, forming the neural tube. The ectoderm closes over the neural tube and 'detaches' from it. Later on, the entire nervous system will develop out of the neural tube.

Also during this period a finger-shaped outgrowth — the allantois, forms by penetrating out of the posterior part of the endoderm into the extraembryonic mesenchyme (the so-called amniotic stalk). The allantois does not carry out any specific functions in humans. Next to the allantois, umbilical blood vessels grow through the amniotic stalk towards the chori-

onic villi. By the end of the 3rd week, the human embryo has the appearance of a trilaminar plate or disk. In the region of the ectoderm a neural tube can be distinguished with the chorda somewhat deeper. Thus, the axial organs of the human embryo are formed.

The fourth week of embryonic development. The trilaminar embryonic disk begins to bend in transverse and longitudinal directions. It becomes convex and its edges are separated from the amnion by a deep groove called the truncal fold. The embryo turns from a flat disk into a volumetric structure. Ectoderm covers the embryo from all sides.

The endoderm inside the embryo rolls up into a tube, forming the embryonic rudiment of the future gut. A narrow opening, which connects the embryonic gut with the yolk sac, later turns into the umbilical ring. The endoderm forms the epithelium and glands of the gastrointestinal tract. The ectoderm forms the nervous system, the dermal epithelium and its derivatives, the epithelial tegument of the mouth, the anal part of the rectum and the vagina. The mesoderm develops into internal organs (excepting the derivatives of the endoderm), the cardiovascular system, organs of the locomotive apparatus (bones, joints, muscles) and the dermis.

The embryonic (primary) gut is at first closed at both ends. Then invaginations appear in the anterior and posterior ends of the embryo, marking the oral cavity and anal fossa. The primary gut cavity is separated from the oral fossa by the double anterior (oropharyngeal) membrane. The gut and the anal fossa are separated by a cloacal (anal) membrane. The anterior (oropharyngeal) membrane breaks in the 4th week of development, while the posterior (anal) membrane breaks in the 3rd month.

As a result of its curving the embryo becomes surrounded by amniotic fluid, which makes up a protective environment and prevents possible damages — primarily mechanical (concussions) — to the embryo. The yolk sac is much slower in growth. In the 2nd month of intrauterine development it appears as a small saccule, and later is reduced completely. The ventral (body, abdominal) stalk, which contains blood vessels that connect the embryo with the placenta, begins to be called the umbilical cord.

Starting with the end of the 3rd and throughout the 4th week the differentiation of the mesoderm continues. Its dorsal part, located at the sides of the chorda, forms paired protrusions called somites. These somites become segmented, meaning divided into paired sections. Because of this, the dorsal part of the mesoderm is called segmented. Segmentation of somites takes place gradually from the front backwards. On the 20th day of development the third pair of somites forms, by the 30th day there are 30 of them, and on the 35th day there are 43–44 pairs. The ventral part of the mesoderm is not
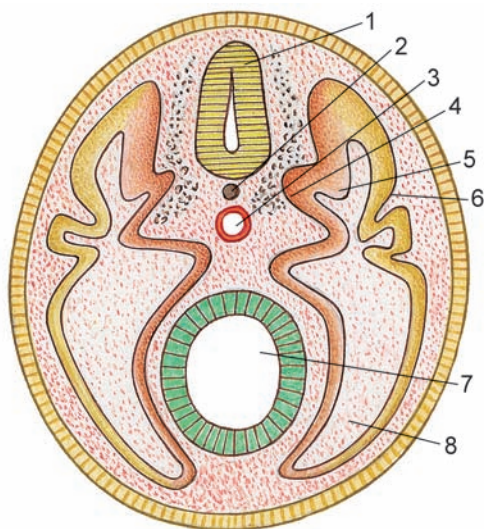
Fig. 31. Transverse section of an embryo.

1 — nervous tube; 2 — chorda; 3 — aorta; 4 — sclerotome; 5 — myotome; 6 — dermatome; 7 — primary intestine; 8 — body cavity.

segmented. It forms plates on either side of the primary gut (Fig. 31). A medial (visceral) plate adjoins the endoderm (primary gut) and is called the splanchnopleura. The lateral (outside) plate adjoins the wall of the embryo (the ectoderm) and is called the somatopleura. The splanchno- and somatopleurae form the epithelial covering of the serosae (mesothelium), as well as the lamina propria serosae and the tela subserosa. The mesenchyme of the splanchnopleura forms all layers of the digestive tube except for its epithelium, which derives from the endoderm. The endoderm forms glands of the esophagus, stomach and intestine as well as the liver with the biliary ducts, the pancreas and epithelial linings of the respiratory organs. The space between plates of the unsegmented mesoderm turns into the celom.

The mesoderm on the border between the somites and the splanchnopleura forms nephrotomes, which form the duct of the mesonephros. The dorsal part of the mesoderm (somites) forms the bones and muscles of the embryonic trunk. The ventromedial region of the somites (sclerotome) forms into bones and cartilage of the axial skeleton — the vertebral column. To the outside of the sclerotome lies the myotome, which forms the skeletal muscles. The dorsolateral region of the somite is called the dermatome, which develops into connective tissue base of the skin, or the dermis.

During the 4th week, in the cranial part of the embryo the ectoderm forms primitive ears (first the aural fossae, following by the aural vesicles) and eyes (future lenses). At this time there is a transformation of the visceral regions of the head, which are grouped around the oral cavity in the form of the frontal and maxillary processes. Caudal of the latter the contours of the mandibular and hyoid visceral arcs can be seen.

On the ventral surface of the embryonic trunk there are several heightenings, namely the cardiac and hepatic tubera. The dent between these

tubera indicates the place of formation of transverse septa — rudiment of the diaphragm.

Caudal of the hepatic tuber is the abdominal stalk, which connects the embryo with the placenta (umbilical cord).

The period between the 5th and 8th weeks is the beginning of organ (organogenesis) and tissue (histogenesis) development. This is the period of early development of the heart and lungs, elaboration in the structure of the gut, formation of the visceral and branchial arches and capsules of sensory organs. The neural tube becomes dilated in the cranial end (future encephalon). At days 31–32 (5th week, length of embryo is approximately 7.5 cm/ finger-like rudiments, 'buds', of the hands form. By day 40 rudiments of the future legs appear.

During week 6 rudiments of the outer ears become noticeable. Starting at the end of weeks 6–7 fingers of the hands, and later toes become visible. By the end of week 7 eyelids begin to form, which makes the eyes appear more defined. By the 8th week formation of organ rudiments becomes complete.

Starting on week 9, or month 3, the embryo begins to appear like a human and starts to be called a fetus. Beginning in third month and during the entire fetal period growth and further development of organs and body parts take place. Differentiation of external sex organs also begins at this time. Rudimentary nails form, and at the end of month 5 eyebrows and eyelashes start to be visible. During month 7 the eyelids open. At this time fat begins to accumulate in the subcutaneous tissue. In the tenth month the fetus is born.

After birth the child grows quickly, his mass, length and surface area of the body increase likewise. A human being grows during the first 20 years of life. For men growth of body length ends at approximately 18–22 years; for women — at 18–20 years. Up to 60–65 years of age body length stays almost constant. During old age (after 60–70 years), however, the length of the body decreases by 1–1.5 mm each year due to the increase of curving in the vertebral column, thinning of intervertebral disks and flattening of foot arcs.

In the course of the first year of life the height of a child increases by 21–25 cm. In the beginning of the second childhood period (8–12 years) height increases at a rate of 4.5–5.5 cm per year and later speeds up. During adolescence (12–16 years) body length increases yearly by 5.8 cm for boys and 5.7 cm for girls. The most intensive growth period for girls is between 10–13 years and for boys — during adolescence (13–16 years). After that growth slows down. The mass of the human body at 5–6 months after birth doubles, and by two years of age increases by 4 times. The
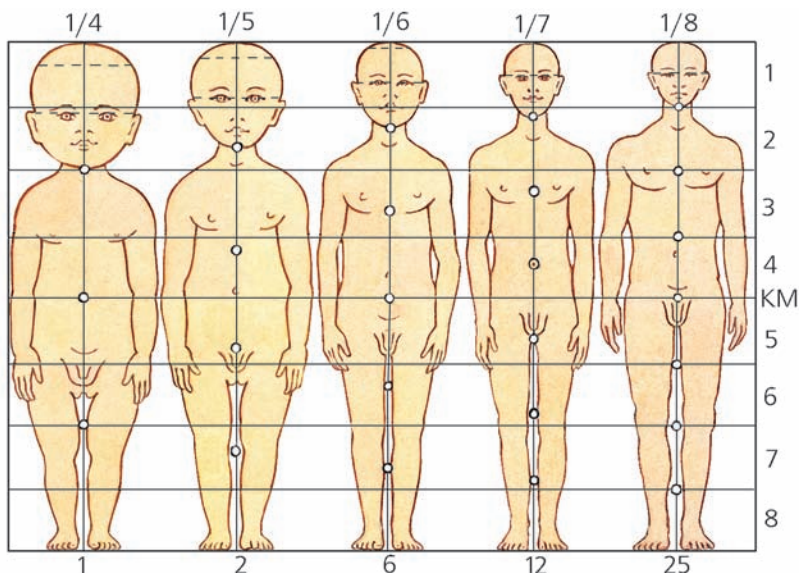
Fig. 32. Modification of body's proportions within the process
of growing (acc. to A. Andronesku).

KM — median line; according to vertical axis (numbers of right side) — correspondence between bodies of childs and adults; superior horizontal axis — correspondence between length of head and body.

maximum yearly mass increase for girls is during the thirteenth year, and for boys during the fifteenth year. Weight continues to increase up to 20–25 years and then remains stable up to age 40–46. It is considered important and physically justified to keep body mass within limits of its values at age 19–20.

During the recent 100–150 years a speeding up (acceleration) of morphological and functional development of the whole body has been noted in children and adolescents. Thus, the body mass for newborns has increased over the century by 100–300 grams, and for one year olds by 1500–2000 grams. Body length during the second childhood period and adolescence increased by 10–15 cm, and for adult males — by 6–8 cm. The time period during which height increases shortened. In the end of the XIX century growth continued until 23–26 years. In the end of the XX century height increases in men until age 20–22, and in women until age 18–20. Dentition of both milk and permanent teeth has accelerated. Mental development and sexual maturation proceed faster. In the end of the XX century, compared to its beginning, the average age of menarche for girls lowered from 16.5 to 12–13 years. The age of menopause for an adult shifted from 43–45 to 48–50 years.

During the postnatal period of growth each age has its morphological and functional characteristics (Fig. 32).

KM-medial line; along the vertical axis, numbers show an accordance of human body portions (concerning children and grown-ups), the upper horizontal axis shows the length concernment of head and body.

A newborn has a relatively large round head, short neck and chest, a long abdomen, short legs and long arms. The cerebral part of the skull is comparatively larger than the facial part. The shape of the thorax is barrel-like. The vertebral column does not have curves. The internal organs are relatively bigger than those of an adult. Thus, the mass of the liver for a newborn makes up 1/20 of total body mass, while in adults it is 1/50. The length of the intestine is twice as long as body length, whereas in adults it is 4–4.5 times as long. The mass of the brain in a newborn makes up 13–14% of the body mass, whereas in an adult it is only approximately 2%. The thymus and adrenal glands are especially large.

During the suckling age (10 days — 1 year) the baby's body grows rapidly. At about 6 months teething of milk teeth begins. During the first year the size of some organs reaches adult size (the eye, inner ear, central nervous system). During the first year of life there is a quick development of organs of the locomotion apparatus, the digestive system and the respiratory system.

In early childhood (1–3 year) primary dentition ends. Psychic development, speech and memory abilities progress quickly. The child starts to become oriented in space. In the end of this period secondary /permanent/ dentition begins. Because of fast development of the brain, the mass of which by now reaches 1100–1200 g, mental capabilities develop quickly, as well as long term ability for recognition and orientation in time and days of the week.

During the second childhood period (3–12 years) growth in width predominates again, although growth in length, which in this period is greater for girls, also increases. The psychic development of children progresses.

Orientation in months and days of the calendar develops. Sexual maturation starts, beginning earlier for girls, due to an increase in female hormone secretion. In girls at the age of 8–9 the pelvis and hips begin to widen, sebaceous gland secretion increases and hair appears on the pubis. In boys of 10–11 year the larynx, testes and penis begin to grow.

In adolescence (12–16 years) sex organs develop quickly and secondary sexual characteristics strengthen. For girls the amount of hair on the pubis increases and hair appears in the axillary fossae. Sexual organs and gonads increase in size. The basic pH of vaginal secretions becomes

acidic, menstruation appears and the size of the pelvis increases. For boys the testes and penis grow quickly. At first, pilosis of the pubis develops as in females and the mammary glands swell. By the end of adolescence (15–16 years) hair growth begins on the face, body, axillar fossae and pubis (male type). The skin of the scrotum becomes pigmented and first ejaculations (involuntary ejaculations) occur. Mechanical and verbo-logical memory develops during adolescence.

Juvenile age (16–21 years) coincides with the period of maturation. During this period growth and development of the organism comes to a conclusion, all apparatuses and organ systems reach a morphological and functional maturity.

The body structure **during mature /adult/ age (22–60)** changes little. During **old age (61–74)** and **senile period (75–90)** certain changes take place that are characteristic of these ages and which are studied by a specialized science—gerontology. Time frontiers of aging vary within a wide range for different individuals. During old age the ability of the organism for adaption decreases.

Questions for revision and examination

1. Name the stages of intrauterine development /between conception and birth/. What are the main structural characteristics of the embryo during each of these periods?

2. Describe the processes that take place in an embryo during the first week of its development.

3. What is implantation of the embryo what is its mechanism?

4. Describe the processes that take place in an embryo during the second week of its development.

5. Describe the processes that take place in an embryo during the third week of its development.

6. What are the embryonic germ layers? When and from what structures do they develop?

7. Describe the developments the embryo goes through during its fourth week.

8. What processes take place in an embryo during the period between the fifth and eighth week of its development?

9. What do you know about acceleration? What changes take place in a human after birth? Name the age periods of postnatal ontogenesis.

LOCOMOTION APPARATUS

There are a lot of different regions in human body (parts).

Two of the most important functions of the body are movement and holding itself in determined position. These functions are carried out by the support and locomotion apparatus, which is made up of active and passive components. The passive component includes bones (hard skeleton), which support muscles and different organs, and joints (Fig.33). The active component of the locomotive system includes muscles, which by contracting bring bone «levers» to movement. The human body also has a soft skeleton (framework), which helps to keep organs near bones. The soft skeleton consists of fascies, ligaments, fibrous capsules and other structures.

STRUCTURE OF BONES

Bone tissue of the hard skeleton, which consists of the vertebral column (spine), the breastbone and ribs (bones of the trunk), skull and bones of upper and lower extremities. The skeleton carries out functions of support, movement, resilience, protection and also serves as a depot for various salts (mineral substances).

The function of support consists in the skeleton providing a hard bone and cartilage framework, to which soft tissues and many organs are attached. The movement function is realized by means of joints, which can be brought to move by muscles. The function of resilience consists in reducing and softening concussions due to movement through the presence of special anatomical structures (construction of the foot, cartilage lining between bones, etc.). The protective function is carried out by providing bone casing for the brain and sensory organs (cavity of the skull) and for the spinal cord (spinal canal). Bones also contain bone marrow, which is the source of blood and immune system cells, and are a depot for mineral salts. A bone contains minute quantities (up to 0.001%) of more than 30 different chemical elements (Ca, P, Mg, etc.).

The skeleton contains an average of 206 bones. Among them there are 36 unpaired and 85 paired bones. The mass of a «living» skeleton is 11 percent of total body weight for newborns and 9–18 percent for children of other ages. In adults this correlation stays at approximately 20 percent throughout the whole life. During old age the mass of the skeleton decreases.
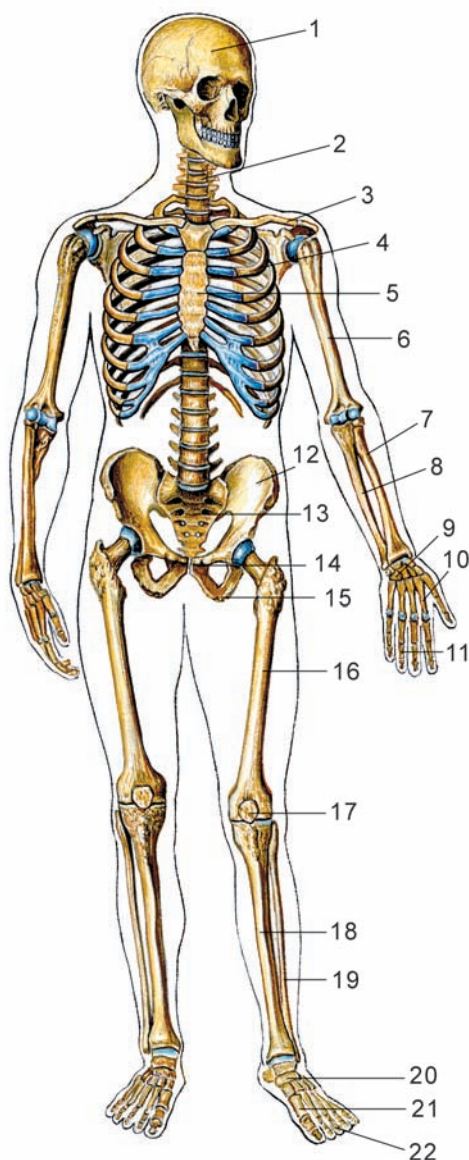
Fig. 33. Human skeleton. Anterior aspect.

1 — cranium; 2 — vertebral column; 3 — clavicle; 4 — rib; 5 — sternum; 6 — humerus; 7 — radius; 8 — ulna; 9 — capral bones; 10 — metacarpals (1—V); 11 — phalanges of fingers of hand; 12 — ilium; 13 — sacrum; 14 — pubis; 15 — ischium; 16 — thigh bone; 17 — patella; 18 — tibia; 19 — fibula; 20 — tarsal bones; 21 — metatarsals; 22 — falanges of fingers of foot.

For research purposes and learning material bones can be macerated (this is attained by degreasing, bleaching and then drying them).

CLASSIFICATION OF BONES

The classification of bones is based on three principles: the shape and structure of a bone, its development and its function. Bones are divided into long (tubular), short (spongy), flat (broad), irregular (mixed) and pneumatic (Fig. 34).

Long bones have a tubular shape and form the basis of limbs. They act as long bony levers. Their diaphysis is usually cylindrical or trihedral (Fig.35). The thickened ends of long tubular bones are called epiphyses. Epiphyses have articular surfaces covered by cartilage, which serve for joining neighboring bones. Between the diaphysis and epiphysis is the part of the bone called metaphysis. This region corresponds to cartilage that has ossified during the course of postnatal development. The metaphysis has a cartilage zone by means of which the bone grows lengthwise. Tubular bones can be subdivided into long (branchial, femoral, etc.) and short bones (metacarpus, metatarsus).

Spongy bones are found in parts of the skeleton, where considerable mobility of bones is combined with great mechanical durability (carpal and tarsal bones). This group also includes sesamoid bones, which lie within
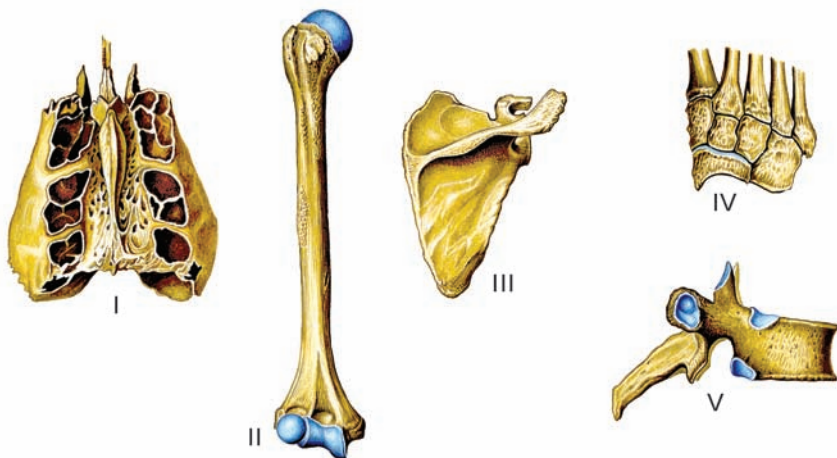
Fig. 34. Types of bones.

I-pneumatized bone (ethmoidal bone); II — long bone; III — flat bone; IV — shot (spongy) bones; V — irregular bone.
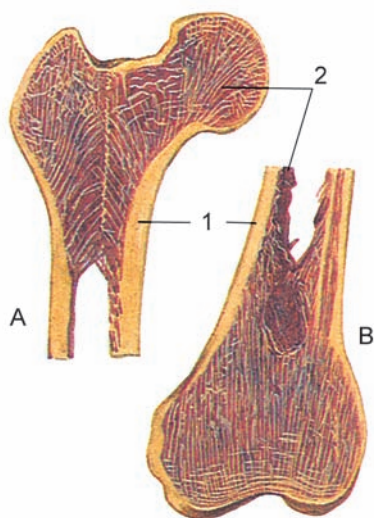
Fig. 35. Proximal (upper) — A — and distal (lower) — B — epiphyses of a thigh bone.

1 — compact bone; 2 — spongy bone.

some tendons. These bones act as blocks, increasing the angle of attachment of tendons to bones, thus optimizing the force of muscle contraction.

Flat bones form walls of cavities and perform a protective function (bones of the skull, pelvis, sternum and ribs). They have significant surfaces for attachment of muscles.

Irregular (mixed) bones have a complex structure, which is a combination of different bone types. For example, the body of a vertebra can be described as spongy bone, while its processes and arc pertain to flat bones.

Pneumatic bones contain cavities lined with mucosa and are filled with air. These include some bones of the skull (frontal, sphenoid, temporal, ethmoid, maxillary). The presence of cavities in these bones decreases the mass of the head. These cavities also act as voice resonators.

The surfaces of all bones have certain undulations on them, which correspond to places of attachment of muscles, fascies and ligaments. Eminencies, processes and tubera are called apophyses. Their formation is promoted by traction of muscle tendons. Places, where muscles attach to their fleshy part, are marked by recesses (pits, fossae). Along the periphery bones are bordered by edges. In places where vessels or nerves adjoin bones, their surfaces are marked with grooves or notches.

STRUCTURE AND CHEMICAL COMPOSITION OF BONES

Bones have a very specific place in the human organism. As any other organ, bones consist of different kinds of tissues, mainly, however, of osteal tissue, which is a variety of connective tissue.

Bones have a complex structure and chemical composition. In living organisms bones are 50 percent water, 28.5 percent organic substances and 21.85 percent inorganic material. The inorganic substances are compounds of calcium, magnesium, phosphorus and other elements. Macer-

ated bone consists by 2/3 of inorganic material and 1/3 organic elements called «ossein».

Durability of bones is created by the physical and chemical unity of their organic and inorganic components and by the way they are structured. Predominance of organic substances provides for the high resilience and elasticity of bones. When the relative content of inorganic substance increases (during senility or certain diseases) bones become brittle and fragile. The proportion of inorganic substances in a bone is not the same for different individuals, and even throughout the life of one person it may vary depending on the quality of nutrition, professional activity, hereditary factors, ecological conditions, etc.

Most of the bones in adults are made up of laminar bone tissue, from which both compact and cancellous (spongy) bones are constructed. The distributions of compact and spongy bone tissue in the skeleton depend on the functional loads on its parts. Compact bone forms diaphyses of tubular bones and covers epiphyses on the outside with thin lamellae (Fig.36). It also covers cancellous and flat bones, which are made up of spongy bone tissue. Compact bone tissue is perforated by thin canals, which contain blood vessels and nerves. Some canals run parallel with the surface of the bone (central or Haversian canals). Others open onto the bone surface in the form of nutrient foramens, through which arteries and nerves enter and veins leave the bone.

Walls of the central (Haversian) canals are formed by concentric lamellae
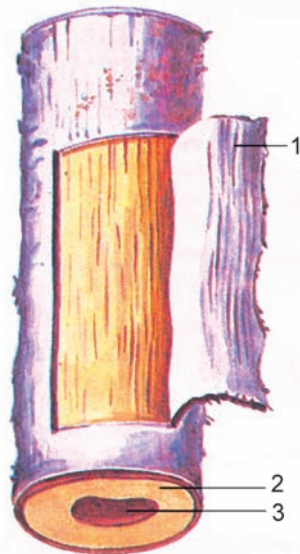
Fig. 36. Structure of diaphysis of tubular bone.

1 — periosteum; 2 — compact bone; 3 — marrow cavity.

Fig. 37. Structure of an osteon.

1 — central canal; 2 — osteonic lamellas; 3 —osteocyte.
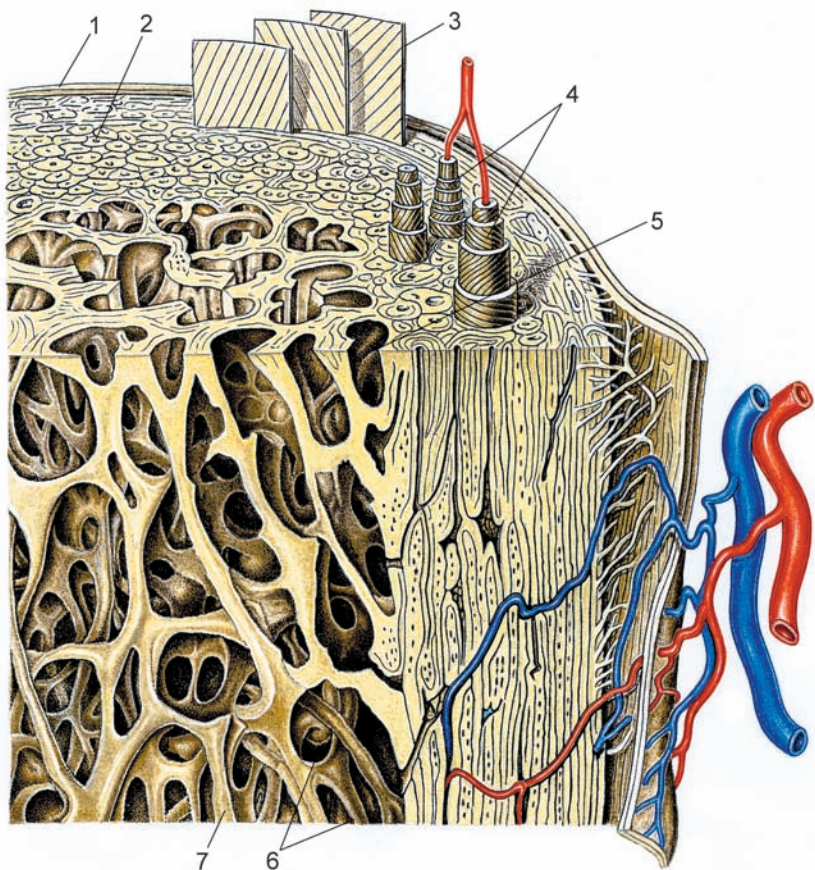
Fig. 38. Structure of tubular bone (acc. to V. Bargman).

1 — periosteum; 2 — compact bone; 3 — layer of external circumferential lamellaes; 4 — osteons; 5 — layer of internal circumferential lamellaes; 6 — marrow cavity; 7 — bone trabeculae of spongy bone.

4–15 mm thick, which are as if inserted one into another. One canal can be encircled by 4–20 such lamellae. The central canals with the surrounding lamellae are called osteons, or Haversian systems (Fig. 37). An osteon is a structural unit of compact substance of a bone (Fig. 38). The space between osteons is filled by intercalary lamellae. The external layer of compact bone is formed by outer lamellae. The internal layer, which limits the medullary cavity, is formed by inner lamellae.

Spongy (cancellous, trabecular) bone has the appearance of a sponge and is formed by bone trabeculae with spaces between them. The size and

positioning of the trabeculae depends on the force exerted on the bone when it is stretched or compressed. Compression and strain curves are hypothetical lines that correspond to the orientation of the trabeculae (Fig. 39). Positioning of the trabeculae at an angle to each other results in more even distribution of pressure (from muscle traction) on the bone. This type of structure determines the durability of bones with a minimum of bone matter used.

The outer surface of bones, excepting their articular surfaces, is covered by a connective tissue membrane called periosteum. The periosteum is attached firmly to the bone by connective tissue fibers, which penetrate into the bone. The periosteum has two layers. The outer fibrous layer is formed by collagen fibers, which give the periosteum firmness. The inner deep layer contains stem elements. It is situated directly to the outside of the bone and contains osteogenic cells by means of which bone can grow in thickness and regenerate after injury. Thus, the periosteum performs protective, trophic and osteogenic functions.

Fig. 39. Positioning of bone trabeculae of the spongy substance in a bone. Cut of the upper extremity of a femur in frontal plane.

1 — lines of pressure; 2 — lines of dilatation.

Bone tissue possesses significant plasticity. It easily reconstructs itself after damage inflicted by training or physical loads. This manifests itself as an increase or reduction in the number of osteons, changes in thickness of lamellae of compact and spongy bone tissue. Optimal development of a bone takes place in conditions of moderate and regular physical loading. Sedentary lives with little physical loads redound to a weakening and thinning of bones. Spaces between lamellae become enlarged, the bone becomes porous and even partially resolves (bone resorption, osteoporosis). Professional activity, environmental and hereditary factors all influence the structure of bones.

Plasticity of bone tissue and its active reconstruction is realized through constant formation of new bone cells and extracellular matrix and parallel destruction (resorption) of old bone. Resorption is a result of osteoclast activity. In place of destroyed bone formation of new lamellae and osteons takes place.

DEVELOPMENT AND GROWTH OF BONES

In its development the skeleton of a fetus passes through several stages, namely mesenchymal (connective tissue, membranous), cartilaginous and osseous. There are two ways of development of bone tissue, depending on the bone's origin. Some bones form directly from embryonic connective tissue, skipping the cartilage stage. Bones of the vault of the skull, for example, are formed in this way (intramembranous ossification). Other bones pass through both membranous and cartilaginous stages. Bones of the trunk, limbs and base of the skull all develop from a cartilage model. In this case bone formation can be endochondral, perichondral and periosteal. Endochondral ossification takes place deep within cartilage; perichondral ossification takes place at the periphery of cartilage (with participation of the perichondrium). Ossification begins in one or several points inside the cartilage model. Around connective fibers and blood vessels that penetrate the cartilage young bone cells (osteoblasts) form trabeculae, which begin to increase in size and grow in different directions. Gradually, osteoblasts develop into mature osteocytes and bone tissue is formed.

Depending on the time period when bone tissue appears in the cartilage model it can be called a primary (main) or a secondary (accessory) center of ossification. Primary centers of ossification appear in diaphyses of tubular bones and most spongy and irregular bones during the first half of the prenatal period. Secondary ossification centers form in epiphyses of tubular bones at the end of prenatal development and after birth (until age of 17–18). These accessory centers of ossification provide for formation of processes, protuberances and crests.

A layer of cartilage (epiphyseal plate) remains between ossification centers of the diaphysis and epiphysis after their formation and is replaced by bone tissue only by age of 18–20. Growth of bone in thickness is promoted by the deep layer of the periosteum.

The medullary canal of tubular bones forms inside the diaphysis by means of resorption of endochondrally formed bone.

First signs of aging of bones manifest themselves as bone protrusions that appear at the periphery of articular surfaces. These are called marginal osteophytes. In hands they most typically appear on caputs of middle phalanges. As aging progresses they also appear in the base of the middle and distal phalanges. Diaphyses tend to widen due to an increase of periosteal osteogenesis. Growth and aging of bones depend on many factors, including the general state of the organism (lifestyle), as well as environmental influences.

1. Name the anatomical formations /organs/ that pertain to the hard and the soft skeleton.
2. Name the functions carried out by the human skeleton.
3. What main characteristics is the classification of bones based on? Give examples.
4. What provides the durability of bones? Explain how and why bone durability changes in people of different ages.
5. What is an osteon and how is it formed?
6. Name the stages and ways of bone formation.

SKELETON OF THE TRUNK

The skeleton of the trunk is part of the axial skeleton. It consists of the vertebral column or spine and the thorax. The vertebral column (colúmna vertebrális) is formed by 33–34 vertebrae; among them there are 7 cervical, 12 thoracic and 5 lumbar vertebrae (Fig. 40). The 5 sacral vertebrae fuse to form one solid bone called sacrum (sacral bone). The coccyx consists of 3–5 coccygeal vertebrae.

VERTEBRAE

All vertebrae have a similar general structure independent of what part of the spine they belong to.

A vertebra (vértebra) consists of a body and an arch (Fig. 41). The v e r t e b r a l   b o d y (córpus vértebrae) is situated to the front and serves as its supporting part. The v e r t e b r a l   a r c h (árcus vértebrae) is connected to the body from behind with two pedicles. Between the body and the arch is the v e r t e b r a l   f o r a m e n (forámen vertebrále). The combination of all these foramina forms the v e r t e b r a l   c a n a l (canális vertebrális), which contains the spinal cord.

The posterior surface of the vertebral body has n u t r i e n t   f o r a m i n a though which nerves and blood vessels (arteries and veins) enter and leave the bone. On the vertebral arch there are processes, which serve as places of attachment for fasciae and muscles. The unpaired s p i n o u s   p r o c e s s (procéssus spinósus) protrudes backwards in the median plane, and to the left and right of the arch are the paired t r a n s v e r s e   p r o c e s s e s (procéssus transvérsus). Upward and downward from the arch protrude the paired s u p e r i o r   a n d   i n f e r i o r   a r t i c u l a r   p r o c e s s e s (procéssus articuláres superióres et inferióres). At the bases of articular processes are the s u p e r i o r   a n d   i n f e r i o r   v e r t e b r a l   n o t c h e s (incisúrae vertebráles supérior et inférior). When two neighboring vertebrae are joined together, these notches form the right and left i n t e r v e r t e b r a l   f o r a m i -
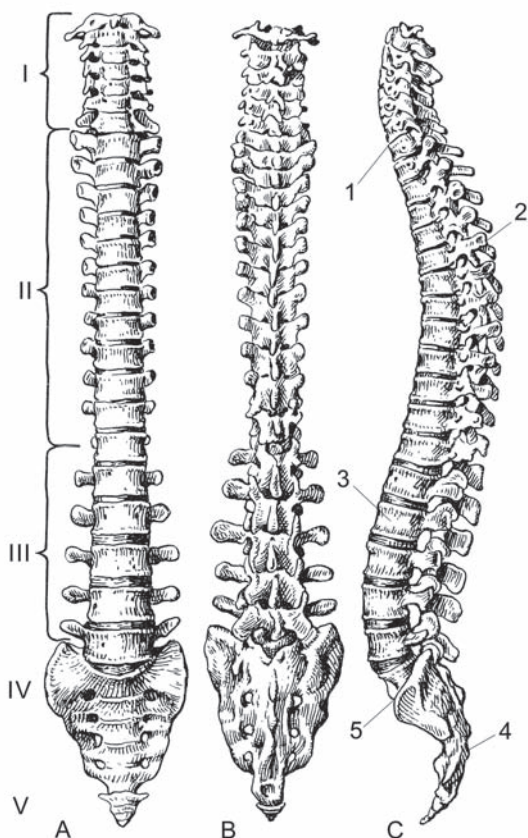
Fig. 40. Vertebral column.

A — anterior aspect; B — posterior aspect; C — lateral aspect (acc. to R. D. Sinelnikov). Parts: I — cervical; II — thoracic; III — lumbar; IV — sacral; V —coccygeal. 1, 3 — cervical and lumbar lordoses; 2, 4 — thoracic and sacral kyphoses; 5 — promontory.

n a. These foramina are passages for blood vessels and spinal nerves. Different groups of vertebrae do, nevertheless, have particular structural characteristics.

Cervical vertebrae

Cervical vertebrae (vértebrae cervicáles) undergo a lesser load in comparison with other sections of the spine, and therefore have a relatively small body. The transverse processes of cervical vertebrae have foramen transversarium (forámen transversárium) going though them. The processes themselves terminate by the a n t e r i o r and p o s - t e r i o r t u b e r c l e s. The anterior tubercles of cervical vertebrae are well developed and are called c a r o t i d t u - b e r c l e s. The carotid arteries pass close by and press against them. The articular processes of cervical vertebrae are relatively short. The spinous processes are short and bifurcated at the ends. The spinal process of the last cervical (C7) vertebra is longer and thicker than its neighboring analogues. It can be easily palpated and is called the vertebra prominence.

The f i r s t c e r v i c a l v e r t e b r a, the atlas (át las) does not have a body (Fig. 42). It is fused with the C2 vertebra during embryonic development, forming its dens. The atlas consists of the anterior and posterior arches, which are joined on the sides by lateral masses. Its

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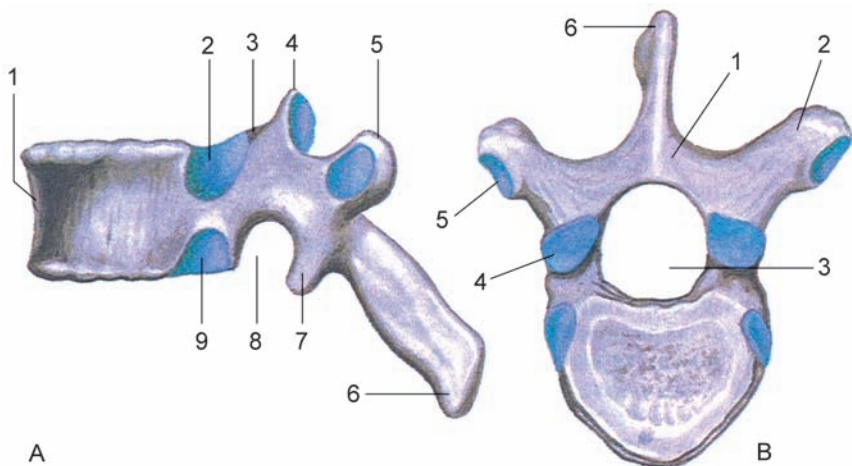
Fig. 41. Structure of thoracic vertebra.

A — lateral aspect: 1 — vertebral body, 2 — superior costal facet; 3 — superior vertebral notch; 4 — superior articular process; 5 — transverse process; 6 — spinous process; 7 — inferior articular process; 8 — inferior vertebral notch; 9 — inferior costal facet. B — superior aspect: 1 — vertebral arch; 2 — transverse process; 3 — vertebral foramen; 4 — superior articular process; 5 — transverse process; 6 — spinous process.

vertebral foramen is large and round. On the front of the a n t e r i o r a r c h is the anterior tubercle. The inner surface of the arch has a recc — the facet for dens, which joins with the dens of the C2 vertebra. The p o s t e r i o r a r c h of the atlas has a p o s t e r i o r t u b e r - c l e, which is considered to be an underdeveloped spinous process. On the top and bottom of each l a t e r - a l m a s s are articular
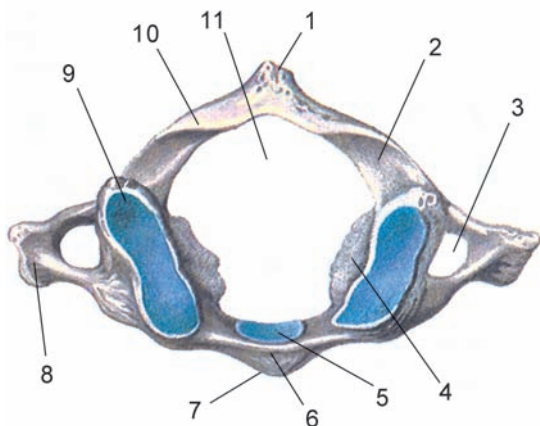
Fig. 42. First cervical vertebra — atlas. Superior aspect.

1 — posterior tubercle; 2 — groove for vertebral artery; 3 — foramen transversarium; 4 — lateral mass; 5 — facet for dens; 6 — anterior arch; 7 — anterior tubercle; 8 — transverse process; 9 — superior articular facet; 10 — posterior arch; 11 —vertebral foramen.

surfaces. The s u p e r i o r a r t i c u l a r s u r f a c e s have an oval shape; these connect with the condyles of the occipital bone. The i n f e r i o r a r t i c u l a r s u r f a c e s are round and participate in forming a joint with the second cervical vertebra. The upper surface of the posterior arch of the atlas has a g r o o v e f o r v e r t e b r a l a r t e r y on either side.
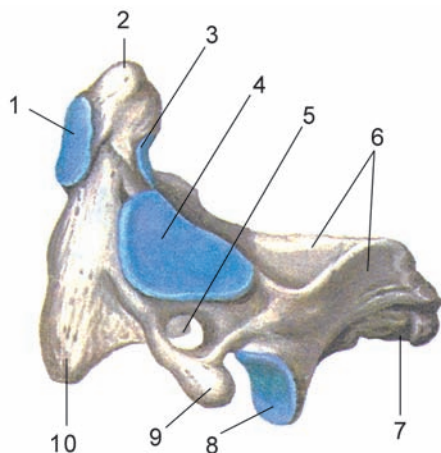
Fig. 43. Second cervical vertebra — axis.
Lateral aspect.

1 — anterior articular facet; 2 — dens; 3 — posterior
articular facet; 4 — superior articular facet; 5 —
foramen transversarium; 6 — vertebral arch; 7 —
spinous process; 8 — inferior articular process; 9 —
transverse process; 10 — vertebral body .

The second cervical vertebra, the axis (áxis) has an odontoid process on the upper part of its body called the d e n s (Fig. 43). The dens has an a p e x and two articular facets (anterior and posterior). The a n - t e r i o r   a r t i c u l a r   f a c e t makes a joint with the facet for dens on the posterior surface of the C1 vertebra, and the p o s - t e r i o r   a r t i c u l a r   f a c e t joins with the transverse ligament of the atlas. On either side of the dens the body of the vertebra has articular surfaces for connecting with the atlas. The inferior articular surfaces of the axis form joints with the third cervical vertebra. All cervical vertebrae have foramina in their transverse processes for the vertebral artery.

Thoracic vertebrae

Thoracic vertebrae (vértebrae thorácicae) are larger than the cervical vertebrae. The height of their bodies increases in downward progression, with the T12 vertebra having the maximum height. Thoracic vertebrae (T2-T9) have s u p e r i o r and i n f e r i o r   c o s t a l   d e m i f a c e t s (fóvea costáles supérior et inférior). A superior costal demifacet of a lower vertebra combines with an inferior costal demifacet of an upper vertebra to form the articular facet for the head of the corresponding rib. T1, T10, T11 and T12 vertebrae have certain characteristic peculiarities. The T1 vertebra has full superior costal facets that articulate with heads of the first ribs, and inferior demifacets. These combine with the superior costal demifacets of the T2 vertebra to create full costal facets for the second ribs. T11 and T12 vertebrae have full costal facets for joints with the corresponding ribs.

The transverse processes of thoracic vertebrae are thickened on the ends. On the anterior sides of these processes are the transverse costal facets, which form costotransverse joints with the tubercles of ribs. T11 and T12 vertebrae do not have facets on their transverse processes. Spinous

processes of thoracic vertebrae long and bent downwards lie overlapping each other. Such positioning prevents excessive bending of the spine. The articular processes are situated in the frontal plane, with the superior articular facets directed laterally and backward and the inferior articular facets — medially and forward.

Lumbar vertebrae

Lumbar vertebrae (vertebrae lumbales) have a large bean-shaped body, the height of which progressively increases from L1 to L5 vertebra. The vertebral foramina are large and almost triangular in shape. The transverse processes are situated nearly in the frontal plane. Spinous processes are flat, short, with thickened ends. Articular facets are directed medially on the superior articular processes and laterally on the inferior articular processes. On each superior articular process there is a very small tubercle called the m a m m i l l a r y p r o c e s s.

Sacrum

The sacrum (os sácrum) consists of five sacral vertebrae (vertebrae sacrales), which fuse into one bone during adolescence (Fig. 44). It is triangular in shape. The sacrum is a massive bone, as it takes on itself the weight of the whole body. The sacrum has a b a s e, an a p e x, a p e l v i c s u r f a c e, which faces forward, and a d o r s a l s u r f a c e. Articular processes on the base of the sacrum form a joint with the inferior articular processes of the L5 vertebra. The anterior edge of the base juts out in the form of a rounded angle called the p r o m o n t o r y. The concave pelvic surface has four t r a n s v e r s e l i n e s, which are traces of fusion between the bodies of the sacral vertebrae. At either side at the same level as these lines are the a n t e r i o r s a c r a l f o r a m i n a (forámina sacrália anterióra, s.pélvica). On the convex dorsal surface of the sacrum there are corresponding p o s t e r i o r s a c r a l f o r a m i n a (forámina sacrália posterióra, s.dorsália). There are five longitudinal crests where processes of sacral vertebrae have fused. The unpaired m i d i a n s a c r a l c r e s t is a result of fusion of the spinous processes. The paired i n t e r m e d i a t e s a c r a l c r e s t s are formed by fusion of the articular processes, and the l a t e r a l s a c r a l c r e s t s are formed through fusion of the transverse processes. On the upper lateral parts of the sacrum there are a u r i c u l a r s u r f a c e s (fácies auriculáres), which form joints with homonymous surfaces on the iliac bones. Between the auricular surfaces and lateral sacral crests there are tuberosities, to which ligaments and muscles attach. Vertebral foramina of the fused sacral vertebrae form the sacral canal, which ends in its lower part by the s a c r a l h i a t u s. On either side this hiatus is confined by the sacral horns, which are rudimental articular processes.
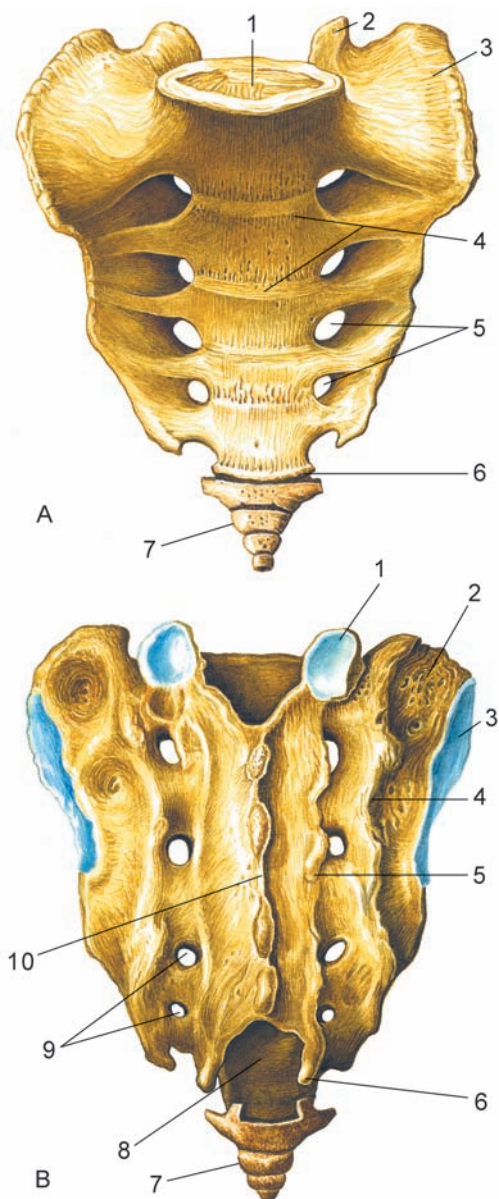
Fig. 44. Sacrum and coccyx.

A — anterior aspect: 1 — base; 2 — superior articular process; 3 — lateral part; 4 — transverse ridges; 5 — anterior sacral foramina; 6 — apex; 7 — coccyx. B — posterior aspect: 1 — superior articular process; 2 — sacral tuberosity; 3 — auricular surface; 4 — lateral sacral crest; 5 — intermediate sacral crest; 6 — sacral horn; 7 — coccyx; 8 — sacral hiatus; 9 — posterior sacral foramina; 10 — median sacral crest.

Coccyx

The coccyx (os cóccygis) forms as a result of fusion of 3–5 rudimental c o c c y g e a l   v e r t e b r a e. It has a triangular shape and is somewhat bent to the front. Its base is directed upwards and the apex — down and forward. It has c o c c y g e a l   h o r n s for joining with the sacrum. In adolescence, especially in women, coccygeal vertebrae are joint with each other by means of layers of cartilage.

RIBS AND STERNUM

The thorax is formed by 12 pairs of ribs, the sternum and the thoracic part of the spine.

The ribs (cóstae) are the long, narrow, thin, curved bone plates (Fig. 45). In the front the bone part of the rib continues into a cartilaginous part called costal cartilage. Ribs can be divided into several groups. The seven upper pairs of ribs, which are joined in front with the sternum, are called
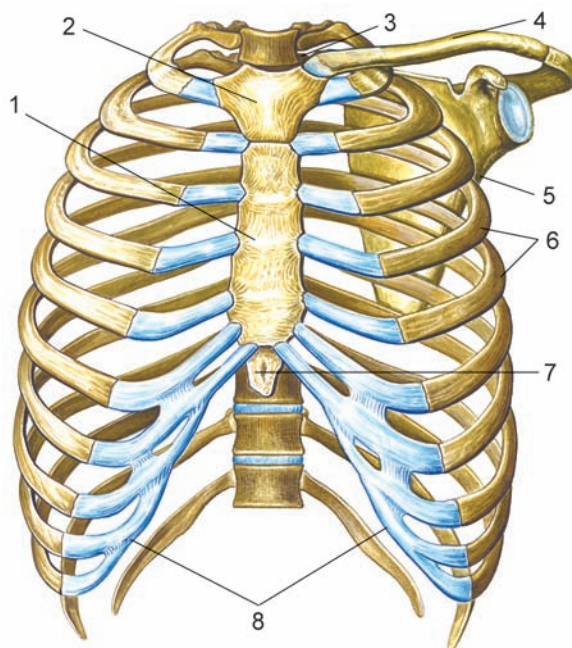
Fig. 45. Skeleton of thoracic cavity. Anterior aspect.

1 — body of sternum; 2 — manubrium of sternum; 3 — superior thoracic aperture; 4 — clavicula; 5 — scapula; 6 — ribs; 7 — xiphoid process; 8 — costal arch.

true ribs (cóstae vérae). Ribs 8, 9 and 10 attach with their cartilaginous parts to the costal cartilage of rib 7. These are called f a l s e r i b s (cóstae spúriae). The ends of ribs 11 and 12 lie free in the thickness of abdominal muscles. These are called f l o a t i n g r i b s (cóstae fluctuántes).

The posterior end of each rib has a thickening called the h e a d (cáput cóstae), which forms a joint with the corresponding costal facet of the thoracic vertebrae. On the head of ribs 2 to 10 there is a c r e s t, which forms because each of these ribs connects with two thoracic demifacets. Heads of ribs 11 and 12 do not have these crests. Next to the head is the narrow n e c k o f t h e r i b (cóllum cóstae), which passes into its b o d y (corpus costae). Ribs 1–10 have a tubercle with an articular facet on the border between neck and body, which articulates with the transverse process of the corresponding vertebra. The flattened rib body has convex e x t e r n a l and concave i n t e r n a l s u r f a c e s. Along the lower edge of the internal surface there is a c o s t a l g r o o v e, against which lie the intercostal blood vessels and nerves.

The first rib differs from all the others by having upper and lower surfaces and lateral and medial edges. Close to where rib 1 joins the sternum, on the upper surface, there is a tubercle of anterior scalene muscle. In front of it is a g r o o v e f o r t h e s u b c l a v i a n v e i n (súlcus vénae subcláviae); behind it is a g r o o v e f o r s u b c l a v i a n a r t e r y (súlcus artériae subcláviae).

Sternum

The sternum, or breastbone, (stérnum) is a flat bone, to which the ribs are attached. It consists of a manubrium, a body and a xiphoid process. The m a n u b r i u m (múnubrium stérni) lies in the wide thick part at the top of the sternum. On its upper edge there is an unpaired j u g u l a r n o t c h, at either side of which are the paired c l a v i c u l a r n o t c h e s, which articulate with the clavicles. On the right and left sides of the manubrium, below the clavicular notches there are c o s t a l n o t c h e s, which articulate with costal cartilage of the first ribs. Somewhat lower there are half-notches, which, together with corresponding half-notches on the body of the sternum, form costal facets for the second ribs. The joint between the manubrium and the body of the sternum is formed at an angle, which opens forward and is called the s t e r n a l a n g l e (ángulus stérni). The b o d y o f t h e s t e r n u m (córpus stérni) is elongated and has costal notches on its sides, which articulate with costal cartilage of the true ribs. The costal notch for rib 5 is situates between the body of the sternum and the xiphoid process. The x i p h o i d p r o c e s s (procéssus xiphoídeus) is sometimes bifurcated.

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MAIN VARIANTS AND ANOMALIES OF BONES OF THE TRUNK

The most frequent variants and anomalies of ribs are the presence of accessory cervical ribs or the absence of rib 12 on one or both sides. The presence of a thirteenth pair of ribs correlates with an increase in the number of thoracic vertebrae. The anterior ends of ribs are sometimes fused or bifurcated.

Fusion of the C1 vertebra with the skull (assimilation of the atlas) may combine with a cleft of the posterior arch of this vertebra. Cleft of a vertebral arch (spina bifida) is more frequent for lumbar and sacral vertebrae. The number of sacral vertebrae can increase at the expense of the last lumbar vertebra (sacralization). Sometimes the number of sacral vertebrae is reduced to 4 with a simultaneous increase in the number of lumbar vertebrae (lumbalization). Sometimes there are foramina in the body and xiphoid process of the sternum.

Questions for revision and examination

1. How do C1 and C2 vertebrae differ from all the other vertebrae?
2. Describe the structure of a typical thoracic vertebra and its differences from cervical and lumbar vertebrae.
3. What anatomic formations are found on the surface of the sacrum?
4. How do ribs 1, 11 and 12 differ from the other ribs?
5. How many facets (notches) are there on the sides of the sternum? What are they for?
6. What variants and anomalies of bones of the trunk do you know?

THE SKULL

The skull (cránium) makes up the skeleton of the head. It is the most complicated part of the skeleton, which serves as a receptacle for the brain, organs of vision, organs of hearing and equilibrium, the olfactory and gustatory organs. It also serves as a support for the initial sections of digestive and respiratory systems. The human skull is made up of 23 bones (8 paired and 7 unpaired) (Fig. 46 and 47).

It consists of the c r a n i a l s k u l l (neurocránium) and the f a c i a l (v i s c e r a l) s k u l l. The neurocranium is situated above the facial bones and contains the brain. The neurocranium is formed by the frontal, occipital, sphenoid, parietal, temporal and ethmoid bones and their junctions. The visceral cranium consists of bones of the masticatory apparatus, namely the upper and lower jaws, as well as small bones, which form walls of the orbit and the nasal and oral cavities. A special position is occupied by the hyoid bone, which is situated in the anterior region of the neck.
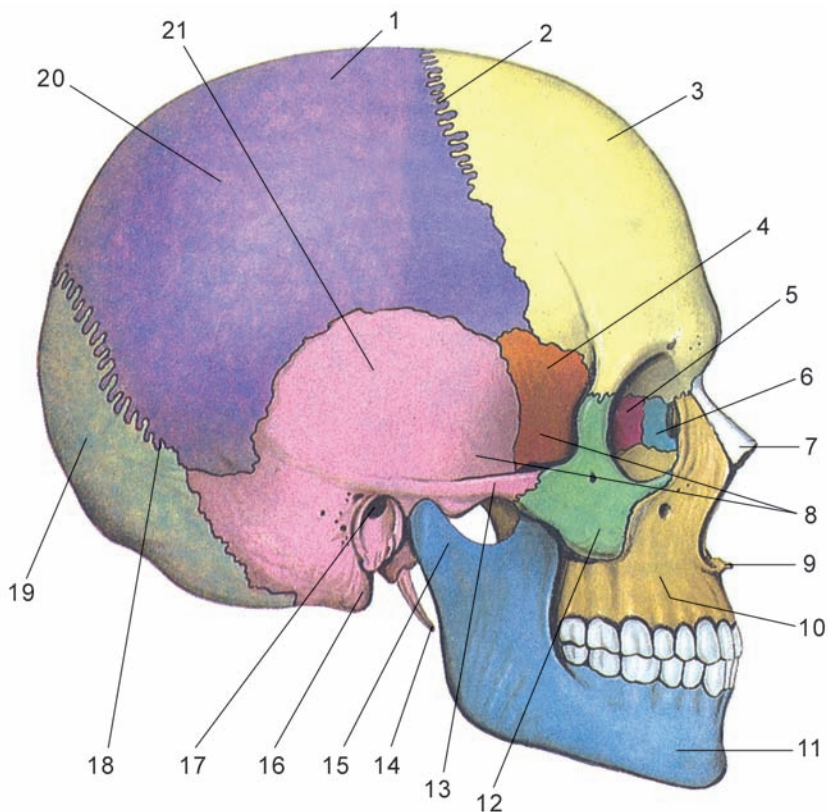
Fig. 46. Human cranium. Lateral aspect.

1 — parietal bone; 2 — coronal suture; 3 — frontal tuber; 4 — temporal surface of greater wing of sphenoid bone; 5 — orbital plate of ethmoidal bone; 6 — lacrimal bone; 7 — nasal bone; 8 — temporal fossa; 9 — anterior nasal spine; 10 — body of maxilla; 11 — mandible; 12 — zygomatic bone; 13 — zygomatic arch; 14 — styloid process; 15 — condylar process of mandible; 16 — mastoid process; 17 — external acoustic opening; 18 — lambdoid suture; 19 — squamous part of occipital bone; 20 — superior temporal line; 21 — squamous part of temporal bone.

BONES OF THE CRANIAL SKULL

The frontal bone (os frontále) takes part in formation of the calvaria of the skull, the anterior cranial fossa and the orbits. The frontal bone consists of the s q u a m o u s p a r t and the orbital and nasal parts.

The f r o n t a l s q u a m a (squáma frontális) has a convex e x t e r n a l s u r f a c e, on which there are two f r o n t a l t u b e r s. On the inside the squama is concave. The frontal squama continues into the o r b i t a l p a r t s, forming the paired s u p r a o r b i t a l m a r g i n. On the supraorbital

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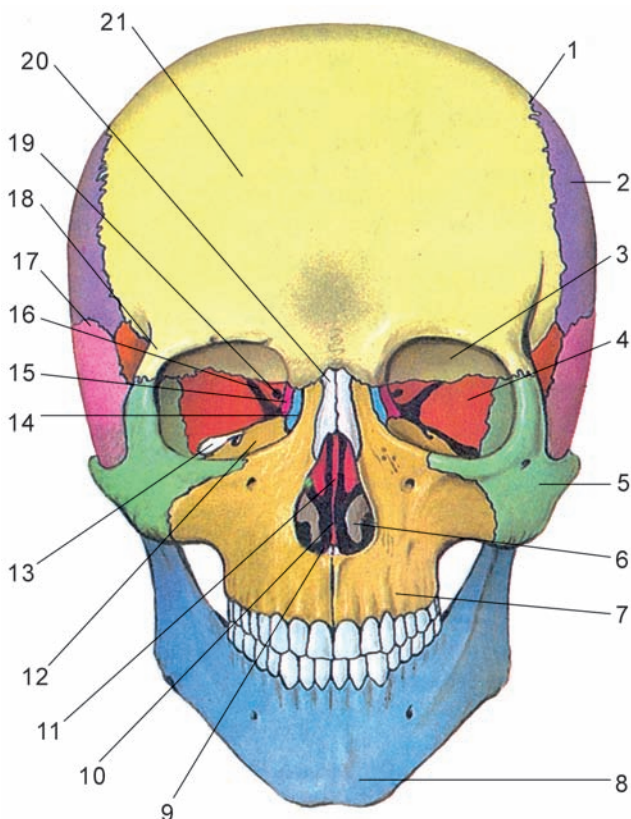
Fig. 47. Human cranium. Anterior aspect.

1 — coronal suture; 2 — parietal bone; 3 — orbital part of frontal bone; 4 — orbital surface of the greater wing of sphenoid bone; 5 — zygomatic bone; 6 — inferior nasal concha; 7 — maxilla; 8 — mental protuberance of mandible; 9 — nasal cavity; 10 — vomer; 11 — perpendicular plate of ethmoidal bone; 12 — orbital surface of maxillae; 13 — inferior orbital fissure; 14 — lacrimal bone; 15 — orbital plate of ethmoidal bone;16 — superior orbital fissure; 17 — squamous part of temporal bone; 18 — zygomatic process of frontal bone; 19 — optic canal; 20 — os nasale; 21 — frontal tuber.

ridge, near the nasal part of the bone, is a s u p r a o r b i t a l n o t c h. Sometimes this notch is present in the form of the s u p r a o r b i t a l f o r a m e n. In the medial part of the supraorbital ridge a small f r o n t a l n o t c h (f o - r a m e n) can usually be found. The lateral supraorbital margin ends as the z y g o m a t i c p r o c e s s, which has a thick base and narrow end. A t e m - p o r a l l i n e passes to the back and upwards from the process. Above the supraorbital ridge on each side there are band-like protuberances called s u p e r c i l i a r y a r c h e s (arcus superciliares). Between the two super- ciliary arches there is a flattened area called g l a b e l l a.

On the i n t e r n a l (cerebral) s u r f a c e of the squama the g r o o v e
f o r t h e s u p e r i o r s a g i t t a l s i n u s is situated along a median line
from front to back. In the front it continues into the f r o n t a l c r e s t, at
the base of which is the so-called foramen caecum.

The o r b i t a l p a r t s (p á r t e s o r b i t á l e s) are thin horizontal
plates, which take part in forming the upper wall of the orbits. Between
them is a deep e t h m o i d a l n o t c h. Near the lateral angle of the orbital
part there is a depression, which is the f o s s a f o r t h e l a c r i m a l
g l a n d. In the medial section of the orbital part there is the t r o c h l e a r
f o v e a, next to which is a bone prominence, called the t r o c h l e a r
s p i n e. Above the orbital part there are so-called digital depressions and
cerebral prominences, which are traces of the grooves and gyri of the brain.

The n a s a l p a r t (p á r t n a s á l i s) of the frontal bone is situated be-
tween the orbital parts and confines from the sides and front the ethmoidal
notch. It has a sharp prominence called the n a s a l s p i n e, at the sides of
which there are foramina, which are o p e n i n g s o f f r o n t a l s i n u s e s.
These sinuses may vary in configuration and size, and are connected with the
nasal cavity.

The sphenoid bone (os sphenoidále) occupies a central part in the
base of the skull. It participates in formation of the lateral parts of the
calvaria of the skull and a number of cavities and fossae. The sphenoid
bone consists of the body, the pterygoid processes and the greater and
lesser wings (Fig. 48).

The b o d y o f t h e s p h e n o i d b o n e (c ó r p u s s p h e n o i d á l e)
has an irregular shape and six surfaces, namely the upper, the lower, the
posterior, which continues into the basal part of the occipital bone, the
anterior and two lateral surfaces. On the upper surface of the body there is
a deep depression called the sella turcica (sélla túrcica), in which is a deep
h y p o p h y s i a l f o s s a. In the back the sella turcica has a dorsum
sellae, and in the front — the t u b e r c u l u m s e l l a e (tubérculum sél-
lae). On each side of the body there is a c a r o t i d s u l c u s (súlcus caróti-
cus), which is where the internal carotid artery adjoins the sphenoid bone.
On the anterior surface of the sphenoid bone there is a s p h e n o i d a l
c r e s t, at either sides of which are the irregularly shaped s p h e n o i d a l
c o n c h a e, which confine the o p e n i n g o f t h e s p h e n o i d s i n u s.
The s p h e n o i d s i n u s is an air-filled cavity, which is connected with
the nasal cavity.

The lateral surfaces of the sphenoid bone body continue into the paired
lesser and greater wings. The l e s s e r w i n g s are bone plates, at the
base of which there are o p t i c c a n a l s, leading into the orbits. The free
edges of the lesser wings are directed backwards and serve as a border
between the anterior and middle cranial fossae.
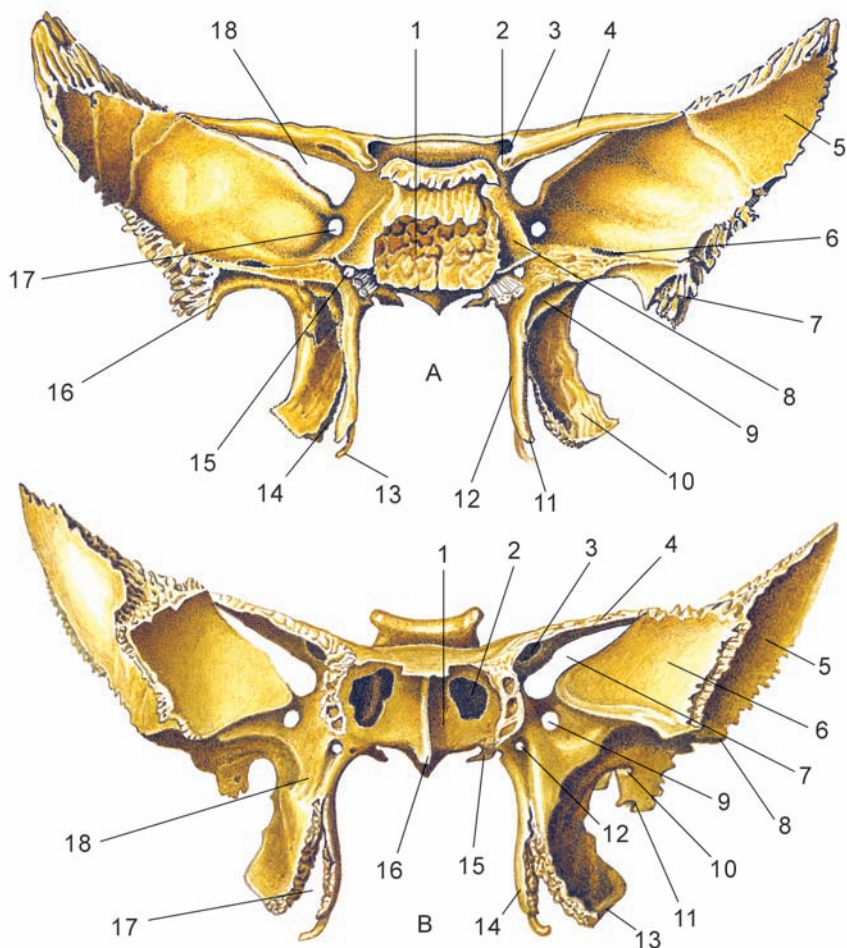
Fig. 48. Sphenoidal bone.

A — posterior aspect: 1 — body; 2 — anterior clinoid process; 3 — optic canal; 4 — lesser wing; 5 — greater wing (cerebral surface); 6 — foramen ovale; 7 — spine of sphenoid bone; 8 — carotid sulcus; 9 — scaphoid fossa; 10 — lateral plate of pterygoid process; 11 — groove of pterygoid hamulus; 12 — medial plate of pterygoid process; 13 — pterygoid hamulus; 14 — pterygoid fossa; 15 — pterygoid canal; 16 — groove of auditory tube; 17 — foramen rotundum; 18 — superior orbital fissure. B — anterior aspect: 1 — body of sphenoid; 2 — apertura (opening) of sphenoidal bone; 3 — optic canal; 4 — minor wing; 5 — greater wing (temporal surface); 6 — orbital surface; 7 — superior orbital fissure; 8 — subtemporal crest; 9 — foramen rotundum; 10 — foramen ovale; 11 — spine of sphenoid; 12 — pterygoid canal; 13 — lateral plate of pterygoid process; 14 — medial plate of pterygoid process; 15 — vaginal process; 16 — sphenoidal rostrum; 17 — pterygoid notch; 18 — maxillar surface.

The anterior edges of the lesser wings connect with the orbital part of the frontal bone and the cribriform plate of the ethmoid bone. Between the lesser wings above and the greater wings below are the upper orbital fissures, which connect the cranial cavity with the orbit.

The g r e a t e r w i n g s begin by a broad base at the lateral surface of the sphenoid bone body. These wings each have 4 surfaces, namely the cerebral, orbital, temporal and maxillary. The c e r e b r a l s u r f a c e faces the cranial cavity. There are 3 foramina on this surface. F o r a m e n r o t u n d u m leads to the pterygopalatine fossa. The f o r a m e n o v a l e is situated at the middle level of the wing. To the back of it is the small f o r a m e n s p i n o s u m. The o r b i t a l s u r f a c e of the greater wing is smooth and takes part in forming the lateral wall of the corresponding orbit. The t e m p o r a l s u r f a c e has an infratemporal crest on it. The m a x i l l a r y s u r f a c e looks into the pterygopalatine fossa.

The pair of p t e r y g o i d p r o c e s s e s are directed downwards from the sphenoid bone. Each process consists of a m e d i a l and l a t e r a l p l a t e s, between which there is a p t e r y g o i d f o s s a. At the base of each p t e r y g o i d p r o c e s s, from back to front passes a narrow p t e r y - g o i d c a n a l.

The occipital bone (os occipitále) is situated in the lower posterior part of the cranial skull. It consists of a basilar part, two lateral parts and the occipital squamous part, all of which surround the foramen magnum.

The b a s i l a r p a r t is located to the front of the f o r a m e n m a g - n u m. In front it is connected with the body of the sphenoid bone, together with which it forms a platform called the c l i v u s.

The l a t e r a l p a r t of the occipital bone continues into its s q u a - m o u s p a r t in the back. On the bottom of each lateral part there is an ellipsoid prominence called the o c c i p i t a l c o n d y l e, through the base of which passes a h y p o g l o s s a l c a n a l. Behind the occipital condyle there is a c o n d y l a r f o s s a, at the bottom of which there is an opening of the c o n d y l a r c a n a l. On the side of the occipital condyle there is a j u g u l a r n o t c h. Near to it, on the cerebral surface of the bone, there is a g r o o v e f o r t h e s i g m o i d s i n u s.

The s q u a m o u s p a r t of the occipital bone has a convex outer surface and a concave inner surface, on which there is a c r u c i f o r m e m i n e n c e. Grooves for the t r a n s v e r s e s i n u s begin to the left and right of the i n t e r n a l o c c i p i t a l p r o t u b e r a n c e and continue into the g r o o v e s f o r s i g m o i d s i n u s. The i n t e r n a l o c c i p i t a l c r e s t passes downwards from the protuberance to the foramen magnum.

The parietal bone (os parietale) is paired. It is broad, convex to the outside and forms the upper lateral parts of the skull vault. The parietal bone has 4 edges, namely the frontal, occipital, sagittal and squamous. The f r o n t a l b o r d e r is located adjacent to the posterior surface of the

frontal squama; the o c c i p i t a l b o r g e r adjoins the occipital squama. Two parietal bones are connected with each other by their s a g i t t a l b o r - g e r. The lower s q u a m o u s b o r g e r is obliquely cut and is overlapped by the squama of the temporal. The parietal bone has four angles, namely the upper anterior f r o n t a l a n g l e, the upper posterior occipital angle, the lower anterior s p h e n o i d a n g l e and the lower posterior m a s t o i d a n g l e.

On the concave surface of the bone, along its whole upper edge, from front to back passes a g r o o v e f o r t h e s u p e r i o r s a g i t t a l s i - n u s. Along this groove there are depressions of different size, which are granulation foveolae made by imprinting of arachnoideal protrusions. In the area of the mastoid angle a deep g r o o v e f o r t h e s i g m o i d s i n u s is situated. On the internal surface of the bone g r o o v e s f o r a r t e r i e s (súlci arteriósi) can distinctly be seen. In the central part of the convex external surface there is a p a r i e t a l e m i n e n c e. Beneath it are the s u p e r i o r a n d i n f e r i o r t e m p o r a l l i n e s, which pass almost parallel to each other along the whole bone.

The ethmoid bone (os ethmoidále) participates in formation of the anterior part of the skull base. It is one of the bones of the facial skull (Fig. 49). It forms together with other bones the walls of the nasal cavity and the orbit. Its upper part consists of the cribriform plate, which is situated in the horizontal cribriform plane and has a lot of foramina. Above it, situated along the median line, is the c r i s t a g a l l i. In the anterior part of the bone, also along the median line, is the f o r a m e n c a e c u m, which is formed by the frontal and ethmoid bones. From the cribriform plate into the nasal cavity projects a p e r p e n d i c u l a r sagittal p l a t e, which forms the anterior part of the nasal septum. At the top, e t h m o i d a l l a b y - r i n t h s are attached to the perpendicular plate on the right and left. These are formed by bony e t h m o i d a l a i r c e l l s.

On the medial side of each ethmoidal labyrinth there are bone promi- nences called the s u p e r i o r a n d m i d d l e n a s a l c o n c h a e. Between them is a narrow superior nasal meatus, and under the middle nasal concha is the middle nasal meatus. Near the posterior part of a middle nasal concha there is the h i a t u s s e m i l u n a r i s, which connects the maxillary sinus with the nasal cavity. The lateral surface of the ethmoidal labyrinth is smooth. It forms part of the medial wall of the orbit and it is called o r b i t a l p l a t e.

The temporal bone (os temporále) is paired and forms part of the base and the lateral wall of the skull. The temporal bone contains organs of hearing and equilibrium. It consists of the petrous, tympanic and squa- mous parts (Fig. 50).

The p e t r o u s p a r t, or p y r a m i d, has a trigonal shape. It is situat- ed obliquely in the horizontal plane. The a p e x of the pyramid is directed medially and to the front; its base is directed laterally towards the back. The pyramid has three surfaces, namely anterior, posterior and inferior.
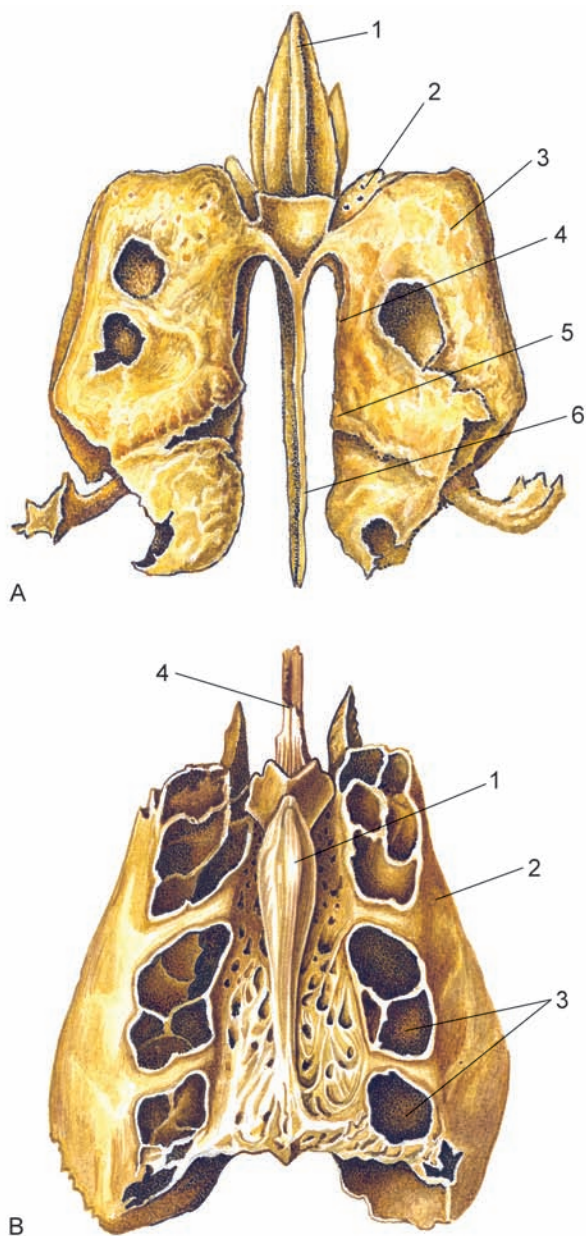
Fig. 49. Ethmoid bone.

A — posterior aspect: 1 — crista galli; 2 — cribriform plate; 3 — orbital plate; 4 — superior nasal concha; 5 — middle nasal concha; 6 — perpendicular plate. B — superior aspect: 1 — crista galli; 2 — orbital plate; 3 — ethmoidal cells; 4 — perpendicular plate.
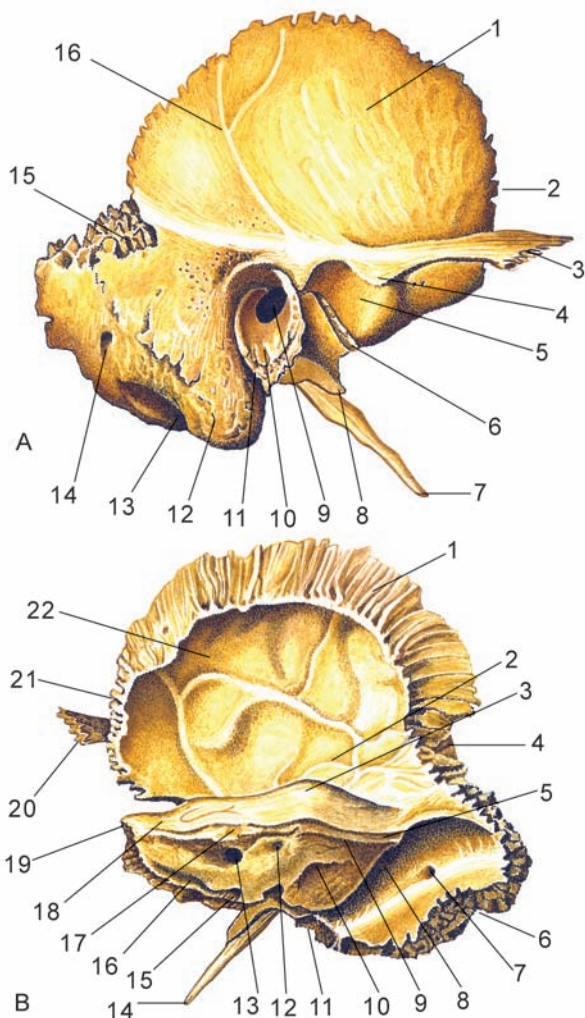
Fig. 50. Temporal bone.

A — external aspect: 1 — squamous part; 2 — sphenoidal margin; 3 — zygomatic process; 4 — articular tubercle; 5 — mandibular fossa; 6 — petrotympanic fissure; 7 — styloid process; 8 — sheath of styloid process; 9 — external acoustic opening; 10 — tympanic part; 11 — tympanomastoid fissure; 12 — mastoid process; 13 — mastoid notch; 14 — mastoid opening; 15 — parietal notch; 16 — groove for middle temporal artery. B — internal surface: 1 — parietal margin; 2 — petrosquamous fissure; 3 — arcuate eminence; 4 — parietal notch; 5 — groove for superior petrosal sinus; 6 — occipital margin; 7 — mastoid foramen; 8 — groove for sigmoid sinus; 9 — posterior surface of petrosal part; 10 — external opening (apertura) of aqueductus vestibuli; 11 — jugular notch; 12 — subarcuate fossa; 13 — internal acoustic opening; 14 — styloid process; 15 — external opening of cochlear canaliculus; 16 — groove for inferior petrosal sinus; 17 — superior border of petrous part; 18 — trigeminal impression; 19 — apex of petrous part; 20 — zygomatic process; 21 — sphenoid margin; 22 — cerebral surface of squamous part.

The a n t e r i o r s u r f a c e faces upwards. Near the apex this surface has a small t r i g e m i n a l i m p r e s s i o n on it, to the lateral side of which there are two foramina. The larger of them is called h i a t u s f o r t h e g r e a t e r p e t r o s a l n e r v e, from which a narrow homonymous groove passes medially towards the front. Laterally and to the font is the h i a t u s f o r t h e l e s s e r p e t r o s a l n e r v e. It continues into the homonymous groove. On the anterior surface of the pyramid there is a flattened area called t e g m e n t y m p a n i, which is the upper wall of the petrous part. Along the upper border of the pyramid there is a g r o o v e f o r t h e s u - p e r i o r p e t r o s a l s i n u s.

In the middle of the posterior surface is the i n t e r n a l a c o u s t i c o p e n i n g leading into the i n t e r n a l a c o u s t i c m e a t u s. Above this opening, to its lateral side, there is a s u b a r c u a t e f o s s a, below and lateral to which is a small external o p e n i n g o f v e s t i b u l a r c a n a l - i c u l u s. Along the posterior edge of the pyramid is a g r o o v e f o r t h e i n f e r i o r p e t r o s a l s i n u s. Near the j u g u l a r f o s s a there is a de- pression, in the bottom of which is the external aperture of the c o c h l e a r c a n a l i c u l u s.

The i n f e r i o r s u r f a c e of the pyramid has a complicated struc- ture. Next to the base of the pyramid is a deep jugular fossa. To the front of the jugular fossa is a round external opening of the carotid canal. Its internal opening is situated on the apex of the pyramid. Between the ex- ternal opening of the carotid canal and the jugular fossa there is a small p e t r o s a l f o s s u l a. Lateral to the jugular fossa a thin and long styloid process points downwards. Behind it is the s t y l o m a s t o i d f o r a m e n. Behind this foramen is the m a s t o i d p r o c e s s, which is broad and can easily be palpated through the skin. This process forms the posterior re- gion of the temporal bone. Inside it there are air-filled cells, which com- municate with the tympanic cavity. Medial to the process there is a deep mastoid notch. To the inside of this notch is the s u l c u s f o r t h e o c - c i p i t a l a r t e r y. At the base of the mastoid process there is sometimes a m a s t o i d f o r a m e n.

The t y m p a n i c p a r t of the temporal bone is formed by a curved narrow bone plate, which confines the e x t e r n a l a c o u s t i c o p e n i n g from above and behind. This foramen leads into the e x t e r n a l a c o u s - t i c m e a t u s. Between the tympanic part and mastoid process there is a narrow t y m p a n o m a s t o i d f i s s u r e. In front of the external acoustic opening is a t y m p a n o s q u a m o u s f i s s u r e. It is divided by a bony crest into the p e t r o s q u a m o u s f i s s u r e, which is situated closer to the m a n d i b u l a r f o s s a, and the p e t r o t y m p a n i c f i s s u r e, which is situated closer to the pyramid.

The s q u a m o u s p a r t is a bone plate, convex to the outside, with an oblique free upper edge. The external t e m p o r a l s u r f a c e of this

part is smooth. On the internal c e r e b r a l s u r f a c e of the squama there are cerebral protuberances, digital depressions and arterial grooves. On the squama, above and to the front of the external acoustic opening, there is a z y g o m a t i c p r o c e s s. This process joins the temporal process of the zygomatic bone, forming the zygomatic arch. Behind the zygomatic process, at its base, is the mandibular fossa, which articulates with the condylar process of the mandible.

Canals of the temporal bone

The pyramid of the temporal bone contains several canals through which cranial nerves and blood vessels pass.

The carotid canal (canális caróticus) begins on the inferior surface of the pyramid at the e x t e r n a l o p e n i n g o f c a r o t i d c a n a l. It is at first directed upwards, then bends nearly at a right angle and goes medially to the front. The canal ends at the i n t e r n a l o p e n i n g o f c a - r o t i d c a n a l at the apex of the pyramid. This canal is a passage for the internal carotid artery and nerves of the carotid plexus into the cranial cavity. From the carotid canal two or three c a r o t i c o t y m p a n i c c a n a l i c u l i branch off and go into the tympanic cavity. These canaliculi contain the homonymous arteries and nerves.

The musculotubal canal (canális musculotubárius) begins at the apex of the pyramid, goes laterally to the back and enters the tympanic cavity. A horizontal septum divides this canal into two parts. One of them is the c a n a l f o r t e n s o r t y m p a n i, which creates tension on the tympanic membrane, and below it is the canal for auditory tube.

The facial canal (canáalis faciális) begins at the internal acoustic meatus. In the beginning it is directed perpendicularly to the long axis of the pyramid. At the level of the hiatus for the greater petrosal nerve it bends at a right angle and continues laterally to the back. Then the canal turns vertically down, rounds the tympanic cavity and ends as the stylomastoid foramen. This canal contains a section of the facial nerve.

The canaliculus for chorda tympani (canáliculus chórdae týmpani) begins at the wall of the facial canal, near its end, and opens into the tympanic cavity. This canal is a passage for the chorda tympani.

The tympanic canaliculus (canáliculus tympánicus) begins at the bottom of the petrosal fossula. Directed upwards, it penetrates the lower wall of the tympanic cavity. Then the canal continues through the medial wall and ends in the region of the hiatus for the lesser petrosal nerve. This canal is a passage for the tympanic nerve.

The mastoid canaliculus (canáliculus mastoídeus) begins in the jugular fossa and ends in the tympanomastoid fissure. Through this canal passes the auricular branch of the vagus nerve.

BONES OF THE FACIAL SKULL

The maxilla (máxilla) is a paired bone. It consists of a body and four processes: alveolar, frontal, palatine and zygomatic (Fig. 51). The b o d y of the bone is irregular in shape and has four surfaces. Its anterior surface is slightly concave. It is separated from the o r b i t a l   s u r f a c e by the i n - f r a o r b i t a l   m a r g i n, beneath which there is an i n f r a o r b i t a l   f o - r a m e n. On the medial edge of the anterior surface there is a deep n a s a l n o t c h, which forms part of the anterior opening of the nasal cavity. The orbital surface forms part of the lower wall of the orbit. In its back region there is an i n f r a o r b i t a l   g r o o v e, which continues to the front into a homonymous canal, which opens as the infraorbital foramen. The i n - f r a t e m p o r a l   s u r f a c e is separated from the anterior surface by the base of the z y g o m a t i c   p r o c e s s. On the infratemporal surface there is a m a x i l l a r y   t u b e r o s i t y (tuber maxillae), on which there are small a l v e o l a r   f o r a m i n a of the a l v e o l a r   c a n a l s. Medial to the tuber is the g r e a t e r   p a l a t i n e   g r o o v e, situated vertically. The n a s a l s u r f a c e of the body forms part of the lateral wall of the nasal cavity. On it is a m a x i l l a r y   h i a t u s, leading into the m a x i l l a r y (Highmore's) s i n u s, which is located inside the body of the maxilla. To the front of the maxillary hiatus is a vertical l a c r i m a l   g r o o v e.

The f r o n t a l   p r o c e s s extends upwards from the body of the maxilla and joins the nasal part of the frontal bone.

The a l v e o l a r   p r o c e s s e s of the two maxillae form the a l v e o - l a r   a r c h, which contains sockets called d e n t a l   a l v e o l i. Each maxilla has alveoli for the roots of eight upper teeth. Alveoli are separated from each other with thin bony septa.

The p a l a t i n e   p r o c e s s is a thick plate, which forms part of the hard palate. In the front part of the process, along the median line, it is pierced through by the i n c i s i v e   c a n a l. In the back it is joined with the horizontal plate of the palatine bone.

The z y g o m a t i c   p r o c e s s begins at the upper lateral part of the body of the maxilla, and extends towards the zygomatic bone.

The palatine bone (os palátinum) forms part of the hard palate, the orbit and of the pterygopalatine fossa. The palatine bone has two plates: the horizontal and the vertical plate, which are attached almost at a right angle. The medial edge of the h o r i z o n t a l   p l a t e joins the edge of the analogous plate of the paired palatine bone. The back edge of the horizontal plate is free. Its front edge attaches to the palatine process of the maxilla. The p e r p e n d i c u l a r   p l a t e of the palatine bone forms part of the lateral wall of the nasal cavity. On the lateral surface of the perpendicular plate is the greater palatine groove. Together with the homonymous grooves
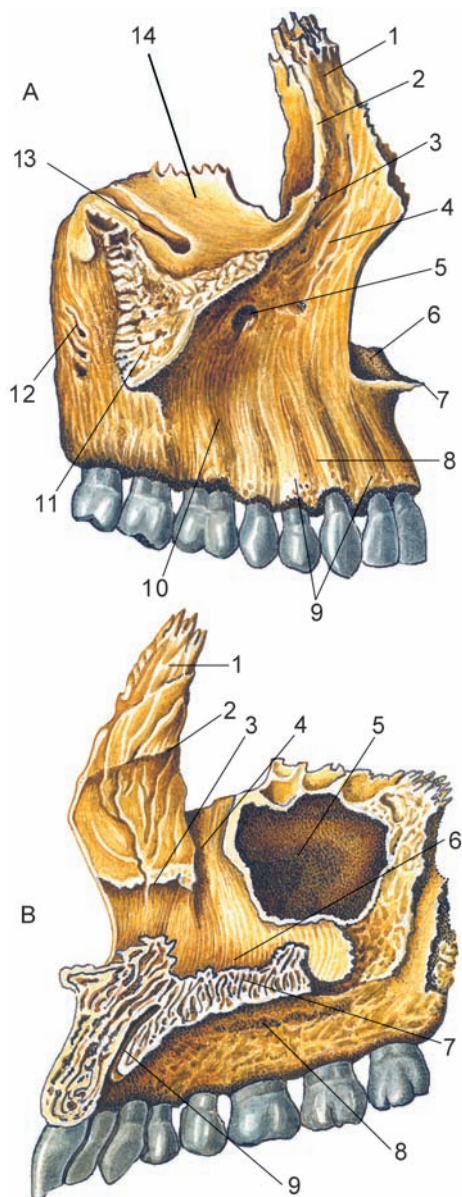
Fig. 51. Maxilla**.**

A — external surface: 1 — frontal process; 2 — anterior lacrimal crest; 3 — infraorbital margin; 4 — anterior surface; 5 — infraorbital foramen; 6 — nasal notch; 7 — anterior nasal spine; 8 — alveolar process; 9 — alveolar yokes; 10 — body of maxilla; 11 — zygomatic process; 12 — tuber of maxilla; 13 — infraorbital groove; 14 — orbital surface. B — internal surface: 1 — frontal process; 2 — ethmoid crest; 3 — conchal crest; 4 — lacrimal groove; 5 — maxillary sinus; 6 — nasal surface; 7 — palatine process; 8 — alveolar process; 9 — anterior nasal spine.

on the maxilla and the pterygoid process it forms the greater palatine canal. On the medial surface of the perpendicular plate there are two horizontal crests. The upper one is the e t h m o i d a l   c r e s t, which serves for attachment of the middle nasal concha. The lower is the c o n c h a l   c r e s t, which serves for attachment of the inferior nasal concha.

The palatine bone has three processes: orbital, sphenoidal and pyramidal. The o r b i t a l   p r o c e s s extends laterally forward and forms part of the lower wall of the orbit. The sphenoid process is directed medially to the back. It attaches to the inferior surface of the sphenoid bone body. The orbital and sphenoid processes confine the sphenopalatine notch. The p y r a m i d a l   p r o c e s s extends from the palatine bone laterally downwards and to the back. This process is perforated by several l e s s e r narrow p a l a t i n e   c a - n a l s, which open as homonymous foramina on its palatine surface.

The inferior nasal concha (cóncha nasális inférior) is a paired, thin, curved plate. It has a body and three processes. The lateral surface of its body is attached by its upper edge to the conchal crest of the maxilla and perpendicular plate of the palatine bone. All the processes of this bone begin at its upper edge. The l a c r i m a l   p r o c e s s extends up to the lacrimal bone. The m a x i l l a r y   p r o c e s s is directed downwards. On the posterior edge of the concha there is an e t h m o i d a l   p r o c e s s, which extends upwards and attaches to the uncal process of the ethmoid bone.

The vomer (vómer) is an unpaired bone plate, which forms part of the nasal septum. Its lower edge attaches to the nasal crest of the maxilla and the palatine bone. Its posterior edge separates the choanae. The anterior edge attaches at the top to the perpendicular plate of the ethmoid bone, and in its bottom section with the cartilaginous nasal septum.

The nasal bone (os nasále) is paired, and forms part of the bony bridge of the nose. The upper edge of the nasal bone attaches to the nasal part of the frontal bone. Its lateral edge articulates with the frontal process of the maxilla. Its lower edge forms part of the piriform aperture, which is the front opening of the nasal cavity.

The lacrimal bone (os lacrimále) is paired and forms the front section of the medial wall of the orbit. With its lower front section the lacrimal bone attaches to the frontal process of the maxilla. In the back it is attached to the ethmoid bone. At the top the lacrimal bone borders with the medial edge of the orbital part of the frontal bone. On the lateral surface of the bone is the p o s t e r i o r   l a c r i m a l   c r e s t. In front of the lacrimal crest is a l a c r i m a l   g r o o v e, which joins with the homonymous groove on the maxilla to form a lacrimal fossa.

The zygomatic bone (os zygomáticus) is paired. It articulates with the frontal bone, the temporal bone and the maxilla, thus strengthening

the facial skull. The zygomatic bone has a lateral, a temporal and an orbital surfaces. The lateral surface faces laterally to the front and is perforated by a small zygomaticofacial foramen. The temporal surface forms the anterior wall of the infratemporal fossa and has a small zygomaticotemporal foramen. The orbital surface, which forms the lower lateral wall of the orbit, is also perforated by a small zygomatico-orbital foramen. The temporal process of the zygomatic bone extends downwards and, together with the zygomatic process of the temporal bone, forms the zygomatic arch. The frontal process extends upwards and attaches to the zygomatic process of the frontal bone and the greater wing of the sphenoid bone.

The mandible (mandíbula) is the only motile bone of the skull. It is an unpaired bone, which has a body and two rami (Fig. 52). The body of the mandible is prominent to the front. Its upper edge forms the alveolar part, which contains dental alveoli that are separated by thin bony interalveolar septa. The front walls of the alveoli bulge forward, forming alveolar yokes on the external surface of the alveolar arch. On the anterior part of the body of the mandible, along the median line, there is a small mental protuberance. To the sides of it, at the level of the second premolar, there are small mental foramina.

In the middle of the concave inner surface of the mandible there is a small protuberance called the mental spine. To the sides of it there is a digastic fossa. Somewhat higher, closer to the alveoli, on either side of the mental spine there is a sublingual fossa, which is an imprinting of the sublingual gland. Also on the internal surface of the mandible body there is an oblique mylohyoid line, beneath which is a submandibular fossa for the homonymous salivary gland.

The ramus of the mandible is paired; it extends upwards and to the back from the mandible body. In the place where the body joins each of the rami there is an angle of the mandible. On its outer surface there is a masseteric tuberosity, and on the inner surface is a pterygoid tuberosity. On the inner surface of each ramus there is a mandibular foramen leading into a homonymous canal, which ends at the mental foramen. At the top the rami diverge into the coronoid and the condylar processes. The coronoid process in the front is separated from the condylar process in the back by the mandibular notch. The condylar process continues into the neck of the mandible, and ends as the head of the mandible.

The hyoid bone (os hyoídeum) is situated in the anterior section of the neck. It is hung to the skull and connected with the larynx by means of muscles and ligaments. The hyoid bone consists of a body and two pairs of processes, namely the greater and lesser horns. The body is curved
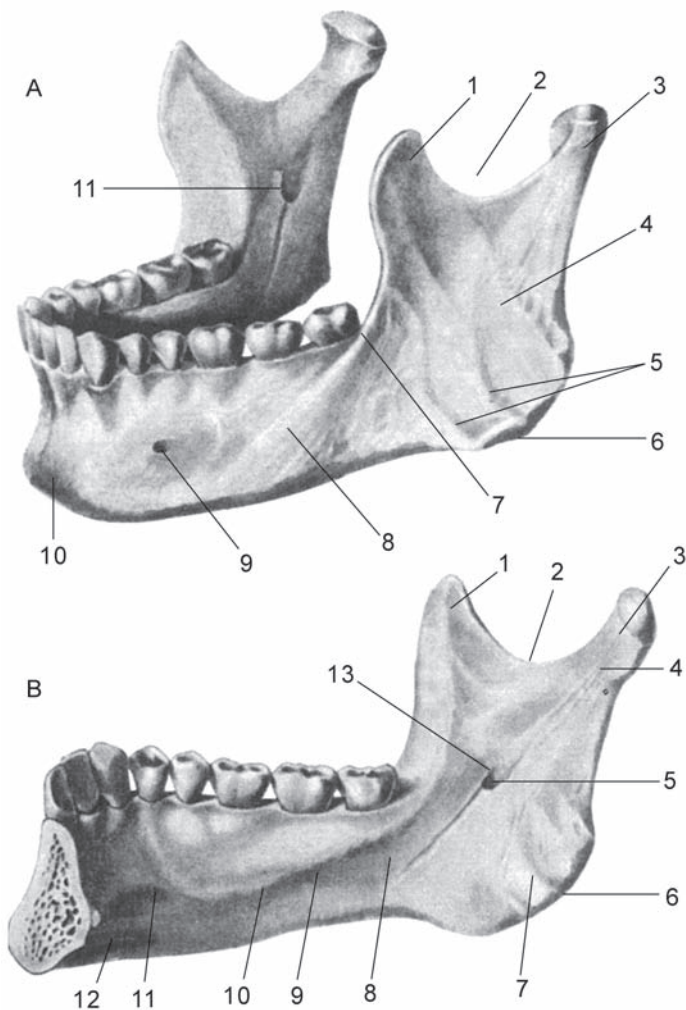
Fig. 52. Mandible.

A — external aspect (from the left and up): 1 — coronoid process; 2 — mandibular notch; 3 — condylar process; 4 — ramus of mandible; 5 — masseteric tuberosity; 6 — angle of mandible; 7 — oblique line; 8 — body of mandible; 9 — mental foramen; 10 — mental protuberance; 11 — mandibular foramen. B — internal aspect: 1 — coronoid process; 2 — mandibular notch; 3 — condylar process; 4 — pterygoid fossa; 5 — mandibular foramen; 6 — angle of mandible; 7 — pterygoid tuberositas; 8 — mylohyoid groove; 9 — mylohyoid line; 10 — submandibular fossa; 11 — sublingual fossa; 12 — digastric fossa; 13 — lingula.

bone plate, prominent to the front. The lesser horns are short and sharpened, and extend from the body laterally and upwards. The greater horns are elongated and thickened at the ends, and extend from the body to the back.

1. How many bones make up the cranial skull and the facial skull? Name these bones.
2. Describe the structure of the frontal bone.
3. Describe the structure of the temporal bone and name its foramina and canals.
4. Name the foramina and canals of the mandible and maxilla.

SKULL AS A WHOLE

The upper part of the cranial skull is called the roof, skullcap or the c a l v a r i a in accordance with its localization. The lower part of the skull is called the b a s e. The r o o f is separated from the base by an imaginary line, which passes across the external occipital protuberance, along the superior nuchal line to the base of the mastoid process and then over the base of the zygomatic process of the temporal bone and the infratemporal crest of the sphenoid bone. The border of the calvaria then extends up to the base of the zygomatic process of the frontal bone, and along its supraorbital margin to the nasofrontal suture. The calvaria consists of the frontal squama, the parietal bones, the squamous parts of the occipital and temporal bones and the lateral parts of the greater wings of the sphenoid bone.

The border between the roof and the base is not designated on the internal surface of the skull, except in its posterior part. There a line can be drawn along the groove of the transverse sinus, which correlates with the superior nuchal line of the outer surface of the occipital bone.

There is a prominent region on the front section of the skull known as the forehead /frons/, which is formed by the frontal squama. On the upper sides of the roof there are prominences called parietal tubers. The anterior side sections of the skull each have two fossae: the temporal and infratemporal.

The temporal fossa /fóssa temporális/ is limited by the inferior temporal line at the top and the infratemporal crest on the bottom. The infratemporal crest separates the temporal and infratemporal fossae.

The infratemporal fossa /fóssa infratemporális/ is well visible on the lateral view of the skull. Its upper wall is formed by the lower part of the greater wing of the sphenoid bone. The medial wall is formed by the lateral plate of the pterygoid process of the sphenoid bone. The anterior wall is formed by the maxillary protuberance and a part of the zygomatic bone. The infratemporal fossa does not have lateral and inferior walls. In the front this fossa is connected with the orbit by the inferior orbital fissure, and from the medial side it is connected with the pterygopalatine fossa through the pterygomaxillary fissure.

The pterygopalatine fossa /fóssa pterygopálatina/ is limited by the maxillary protuberance in the front, the base of the pterygoid process of
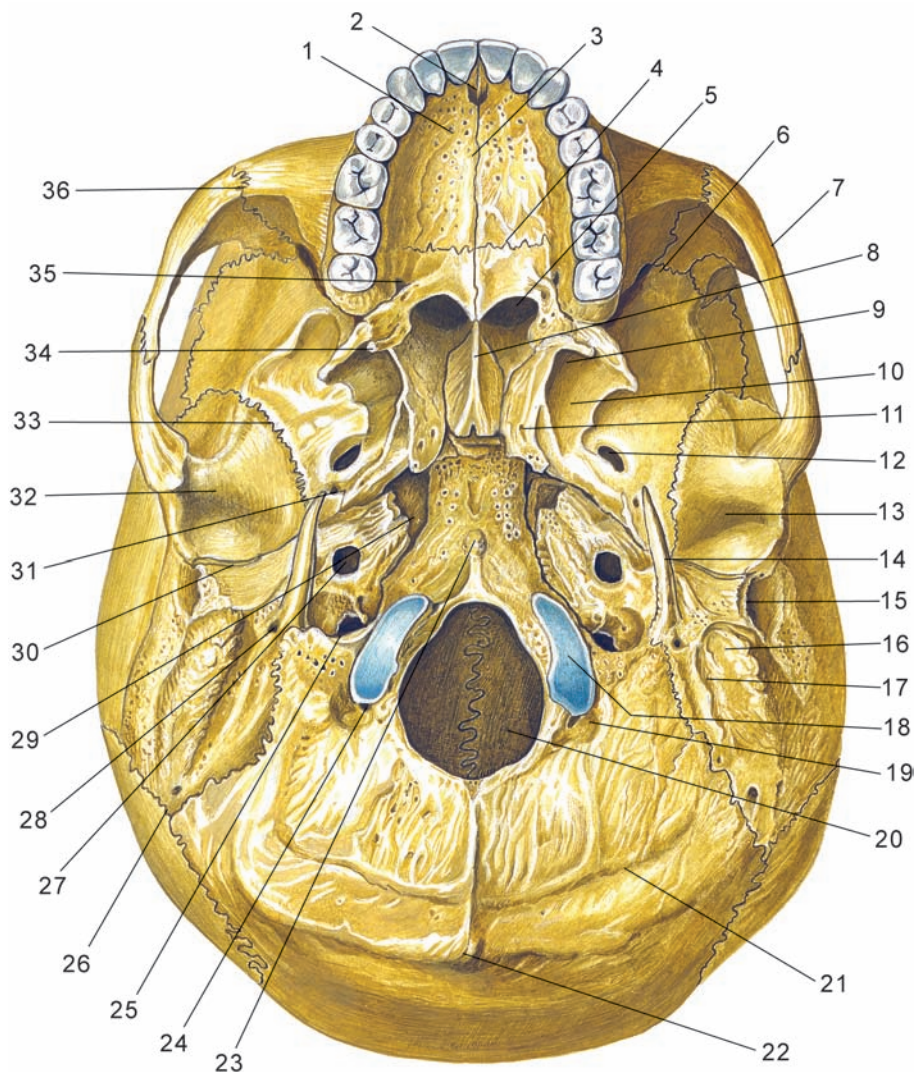
Fig. 53. External surface of cranium base.

1 — palatine process of maxilla; 2 — incisive foramen; 3 — median palatine suture; 4 — transverse palatine suture; 5 — choane; 6 — inferior orbital fissure; 7 — zygomatic arch; 8 — vomer wing; 9 — pterygoid fossa; 10 — lateral plate of pterygoid process; 11 — pterygoid process; 12 — oval opening; 13 — mandibular fossa; 14 — styloid process; 15 — external acoustic opening; 16 — mastoid process; 17 — mastoid notch; 18 — occipital condyle; 19 — condylar fossa; 20 — foramen magnum; 21 — inferior nuchal line; 22 — external occipital protuberance; 23 — pharyngeal tubercle; 24 — condylar canal; 25 — jugular opening; 26 — occipitomastoid suture; 27 — external carotid opening; 28 — stylomastoid opening; 29 — foramen lacerum; 30 — petrotympanic fissure; 31 — spinous foramen; 32 — articular tubercle; 33 — sphenoidosquamous suture; 34 — pterygoid hamulus; 35 — greater palatine opening; 36 — zygomaticomaxillar suture.

the sphenoid bone in the back, and by the perpendicular plate of the palatine bone on the medial side. The pterygopalatine fossa has no lateral wall and connects on this side with the infratemporal fossa. Five foramina open into the pterygopalatine fossa. On the medial side it communicates with the nasal cavity through the sphenopalatine foramen and with the middle cranial fossa through the foramen rotundum. In the back the pterygopalatine fossa communicates with the region of the lacerated foramen through the pterygoid canal, with the orbit through the inferior orbital fissure and with the oral cavity though the greater palatine canal. These and several other foramina serve as passages for blood vessels, cranial nerves and their branches.

The external base of the skull (básis cránii extérna) can not be seen from the front, because it is covered by the facial skull (Fig. 53, table 1).

It can be seen, however, that in the back it is formed by external surfaces of the temporal, sphenoid and occipital bones. The center of this region is the foramen magnum. Occipital condyles and condylar fossae are situated on the inferior surface of the external base. The base of each condyle is pierced through by a hypoglossal canal of the homonymous nerve. On either side of the occipital bone is an inferior surface of the pyramid of the temporal bone, on which one can see the external opening of the carotid canal, the musculotubal canal, the jugular fossa and the jugular notch. This notch forms the j u g u l a r f o r a m e n together with the jugular notch of the occipital bone. Also on the inferior surface of the pyramid are the styloid process, the mastoid process and the stylomastoid foramen, though which the facial nerve exits the skull. Lateral to the pyramid is the tympanic part of the temporal bone, which surrounds the external acoustic opening. In the back the tympanic part is connected with the mastoid process by the tympanomastoid fissure. The foramen ovale and foramen spinosum can be seen on the back part of the greater wing of the sphenoid bone, which lies between the petrous and squamous parts of the temporal bone. The pyramid and the greater wing of the sphenoid bone are separated by the petro-occipital fissure. There is also a f o r a -m e n l a c e r u m, which is limited laterally and from behind by the apex of the pyramid and the greater wing of the sphenoid bone.

The internal base of the skull (básis cránii intérna) has a concave surface. It is divided into the anterior, posterior and middle cranial fossae, in the bottoms of which there are various foramina (Fig. 54, table 2).

The a n t e r i o r c r a n i a l f o s s a (fóssa cránii antérior) is formed by the orbital parts of the frontal bone. The boundary between the anterior and middle fossae is the posterior edge of the lesser wings of the sphenoid bone. The cribriform plate of the ethmoid bone is situated in the central
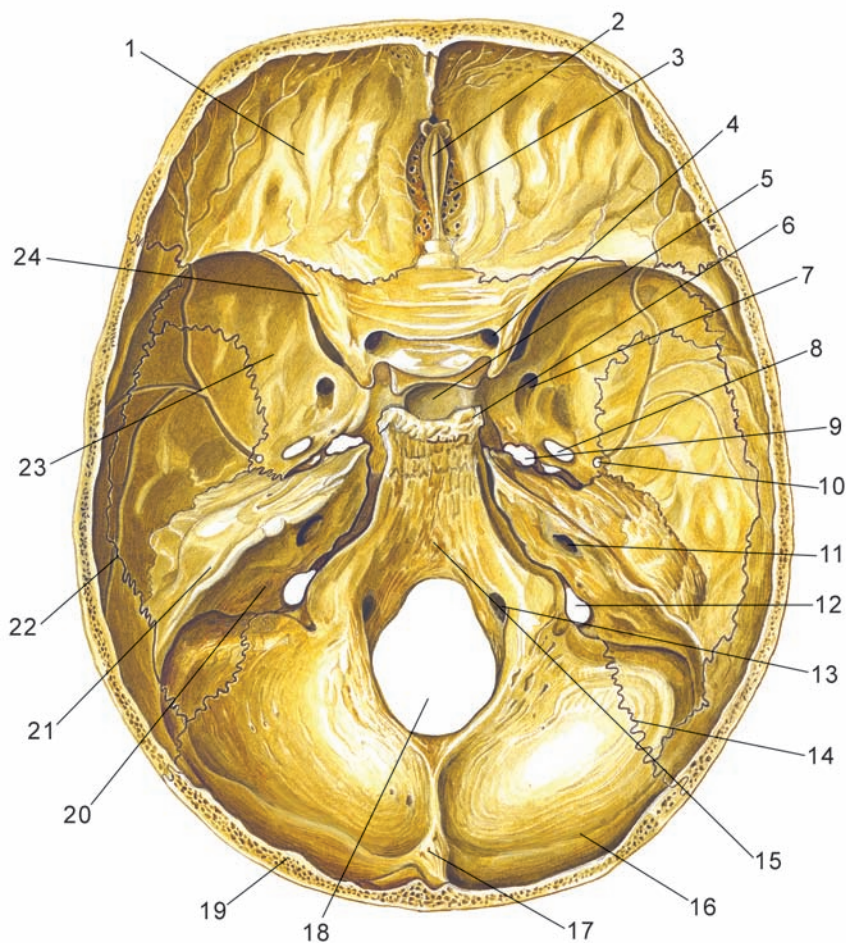
Fig. 54. Internal surface of cranium base.

1 — orbital part of frontal bone; 2 — crista galli; 3 — cribriform plate; 4 — optic canal; 5 — hypophisial fossa; 6 — dorsum sellae; 7 — foramen rotundum; 8 — foramen ovale; 9 — foramen lacerum; 10 — foramen spinosum; 11 — internal acoustic opening; 12 — jugular foramen; 13 — hypoglossal canal; 14 — lambdoid suture; 15 — clivus; 16 — groove for transverse sinus; 17 — internal occipital protuberance; 18 — foramen magnum; 19 — squamous part of occipital bone; 20 — groove for sigmoid sinus; 21 — pyramis; 22 — squamous part of temporal bone; 23 — greater wing of sphenoidal bone: 24 — lesser wing of sphenoidal bone.

part of the anterior cranial fossa. The m i d d l e   c r a n i a l   f o s s a (fóssa cránii média) is formed by the body and greater wings of the sphenoid bone. It is separated from the posterior cranial fossa by the superior margin of the pyramid of the temporal bone and the dorsum of sella turcica.

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The sella turcica is situated in the center of the middle cranial fossa. At its bottom is the pituitary fossa, in front of which is the prechiasmatic groove. On either side of this groove is an opening into the optic canal, which leads into the orbit. At each side of the sella turcica there is a carotid groove, formed by the adjoining carotid artery. Near the top of the pyramid of the temporal bone there is a lacerated foramen. Between the greater and lesser wings of the sphenoid bone is the superior orbital fissure, which connects the middle cranial fossa with the orbit. To the back of this fissure is the foramen rotundum, behind which is the foramen ovale. The foramen spinosum is situated laterally and to the back of the foramen ovale. In the posterior region of the middle cranial fossa, on the anterior surface of each pyramid there is a trigeminal impression of the large trigeminal ganglion of the homonymous nerve. Also on this surface are the hiatuses of the greater and the lesser petrosal nerves, grooves for the greater and lesser petrosal nerves and the arcuate prominence of the tegmen tympani. The p o s t e r i o r   c r a n i a l   f o s s a (fóssa cránii postérior) is formed by the occipital bone, posterior surfaces of the pyramids and part of the sphenoid bone body. In the back the posterior cranial fossa is limited by the groove of the transverse sinus. In the center of this fossa is the foramen magnum. In front of the foramen magnum there is a slightly sloping platform called the clivus, formed by fusion between bodies of the occipital and sphenoid bones. Behind the foramen magnum is the internal occipital crest. The posterior cranial fossa contains the internal auditory openings, which lead into the internal acoustic canals. The right and left jugular foramina and hypoglossal canals are also well seen.

Bones of the facial skull form parts of walls of the orbit, nasal and oral cavities and pterygopalatine and infratemporal fossae.

The o r b i t (o r b ít a) has the shape of a quadrilateral pyramid (Fig. 55). It contains the eyeball and the accessory apparatus of the eye, including muscles, the lacrimal glands, etc. The orbit has four walls, namely the superior, inferior, lateral and medial. The superior wall is formed by the orbital part of the frontal bone and the lesser wing of the sphenoid bone (from behind). The inferior wall consists of orbital surfaces of the maxilla and zygomatic bone and the orbital process of the palatine bone. The inferior wall has an infraorbital groove, which continues into the infraorbital canal in the front. The medial wall is formed by the frontal process of the maxilla, the lacrimal bone, the orbital plate of the ethmoid bone and the sphenoid bone body. The upper part of the medial wall is formed by the medial section of the orbital portion of the frontal bone.

The lower anterior part of the medial wall contains the n a s o l a c r i m a l   c a n a l (canális nasolacrimális), which opens into the inferior meatus of the nasal cavity. Above the o p e n i n g   o f   t h e   n a s o l a c r i m a l
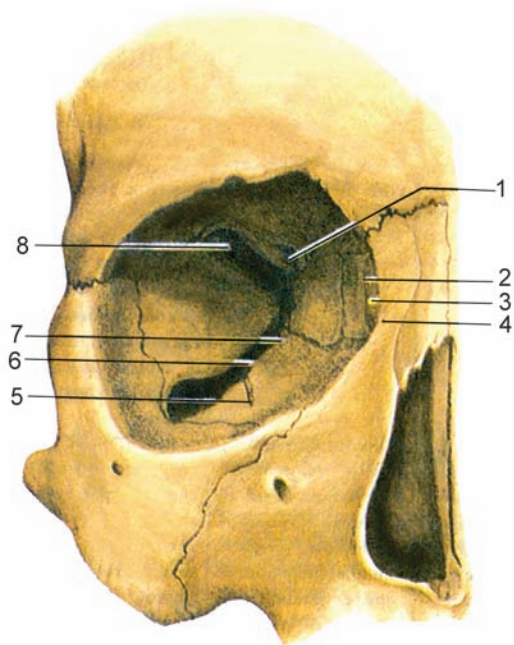
Fig. 55. Orbita. Anterior aspect.

1 — optic canal; 2 — posterior lacrimal crest; 3 — fossa for lacrimal sac; 4 — anterior lacrimal crest; 5 — infraorbital groove; 6 — inferior orbital fissure; 7 — orbital process of palatine bone; 8 — superior orbital fissure.

canal is the fossa of the lacrimal sac. Behind and above this fossa, in the suture between the frontal bone and the orbital plate of the ethmoid bone are the anterior and posterior ethmoid foramina. The lateral wall is formed by the orbital surfaces of the greater wing of the sphenoid bone, the frontal process of the zygomatic bone and a small portion of the zygomatic process of the frontal bone. Between the lateral and the medial wall is the superior orbital fissure, which leads into the middle cranial fossa.

The inferior orbital fissure is also situated between the lateral and medial walls and connects the orbit with the pterygopalatine and infratemporal fossae. On the lateral orbital wall, in the area of the orbital surface of the zygomatic bone, is the zygomatico-orbital foramen. This foramen leads into a canal, which bifurcates and ends as the zygomaticofacial and zygomaticotemporal foramina on the lateral and temporal surfaces of the zygomatic bone accordingly.

The nasal cavity (cavum nasi) consists of a right and left halves, separated by the nasal septum. The bony nasal septum is formed by the perpendicular plate of the ethmoid bone, connected with the vomer. The front of the nasal cavity opens as the piriform aperture. The piriform aperture is formed by the nasal notches of the maxillae and the lower borders of the nasal bones. The posterior openings of the nasal cavity, which are called choanae (choánae), lead into the nasatpharynx. The choanae are limited by the medial plates of pterygoid processes on the lateral sides, the vomer on the medial side, the body of the sphenoid bone at the top and the horizontal plates of the palatine bones on the bottom.

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The nasal cavity has superior, inferior and lateral walls. The superior wall is formed by the nasal bones, the nasal part of the frontal bone, the cribriform plate of the ethmoid bone and the inferior surface of the sphenoid bone. The inferior wall of the nasal cavity is formed by the palatine processes of the maxillae, connected with the horizontal plates of the palatine bones. The lateral wall has the most complex structure (Fig. 56).

It is formed by the frontal processes of the maxillae and the nasal surface of its body, the lacrimal bone, the ethmoidal labyrinths, the per-
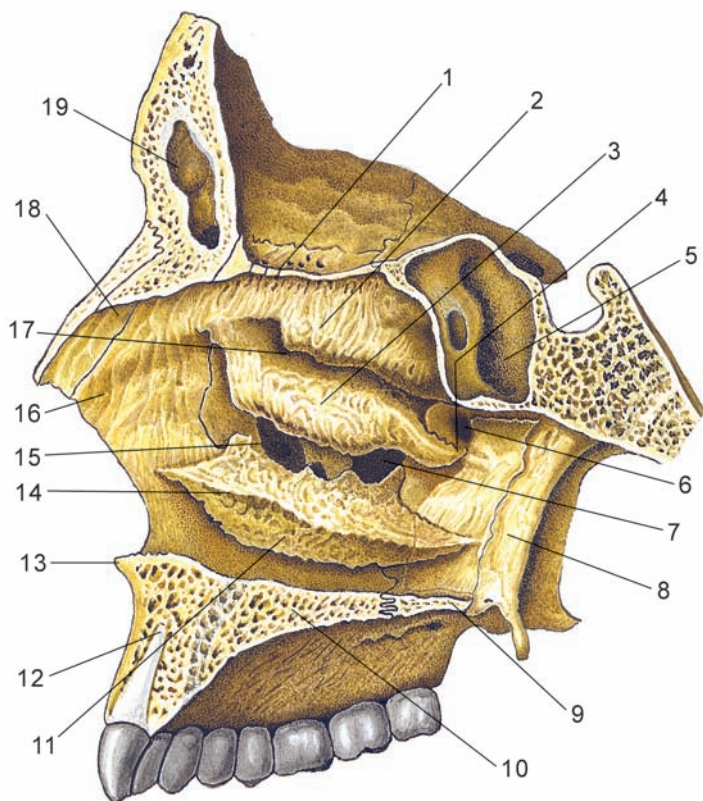
Fig. 56. Lateral wall of nasal cavity.

1 — cribriform plate; 2 — superior nasal concha; 3 — medial nasal concha; 4 — uncinate process of ethmoidal bone; 5 — sphenoid sinus; 6 — sphenopalatin foramen; 7 — maxillary hiatus; 8 — medial plate of pterygoid process; 9 — horisontal plate of palatine bone; 10 — palatine process of maxilla; 11 — inferior nasal concha; 12 — incisive canal; 13 — anterior nasal spine; 14 — inferior nasal meatus; 15 — middle nasi meatus; 16 — frontal process of maxilla; 17 — superior nasi meatus; 18 — nasal bone; 19 — frontal sinus.

pendicular plates of the palatine bones and the medial plates of the ptery-goid processes. There are three bony nasal conchae fixed on the lateral wall: the superior and middle nasal conchae (parts of the ethmoid bone) and the inferior nasal concha (an independent bone). Between the con-chae there are three nasal meatuses: the superior, middle and inferior.

The superior nasal meatus (meátus nási supérior) is situated in the back section of the nasal cavity. It is the shortest and is limited by the superior and middle nasal conchae. It communicates with posterior ethmoidal air cells and the sphenoid sinus.

The middle nasal meatus (meátus nási médius) is situated under the middle nasal concha. It is twice as large as the superior meatus and is limited by the middle and inferior nasal conchae. It is com-municated with the anterior and middle ethmoidal air cells, the frontal and the maxillary (Highmore) sinuses. Behind the middle nasal concha is the sphenopalatine foramen, which connects the middle nasal meatus with the pterygopalatine fossa.

The inferior nasal meatus (meátus nási inférior) is formed between the inferior nasal concha and the bottom of the nasal cavity. It contains the opening of the nasolacrimal canal.

Paranasal sinuses

The maxillary (Highmore) sinuses are cavities inside the maxilla. The anterior wall of each sinus is very thin in the center and gets thicker at the periphery. This wall is formed by a part of the maxilla between the infraorbital border and the alveolar process. Its lateral posterior wall cor-responds to the maxillary tuber. The nasolacrimal duct passes within the anterior section of the medial wall, and the ethmoidal air cells lie close to its upper posterior section. The inferior wall is formed by the alveolar process of the maxilla. The superior wall of each sinus simultaneously acts as the inferior wall of an orbit. The maxillary sinuses open into the middle nasal meatus. The shape and size of these sinuses varies between individuals.

The frontal sinuses (sínus frontális) are highly variable in size. The septum dividing the left and right frontal sinuses is frequently asym-metrical. The frontal sinuses are communicated with the middle nasal meatuses.

The sphenoidal sinus (sínus sphenoidális) is located inside the body of the sphenoid bone. Its inferior wall forms part of the wall of the nasal cavity. The upper part of the lateral walls lies adjoining the cavernous sinuses. The sphenoidal sinus is frequently divided into two asymmetrical

parts by a sagittal septum, although sometimes this septum is absent. The sphenoidal sinus is connected with the superior nasal meatus.

The anterior, middle and posterior ethmoid air cells are communicated with the nasal cavity.

The bony (hard) palate (palátum ósseum) is the bone base of the upper wall of the oral cavity and the bottom of the nasal cavity. The hard palate is formed by the palatine processes of the right and left maxillae and horizontal plates of the palatine bones, joint along the middle line by the median palatine suture. The alveolar arch of the maxillae limits the hard palate at the front and sides. In the anterior section of the median suture there is a foramen called the i n c i s i v e   c a n a l. The posterior borders of palatine processes are joined with the horizontal plates of the palatine bone by the transverse palatine suture. Behind the lateral section of this suture, on each horizontal plate, there is an opening of the g r e a t e r   p a l a t i n e   c a n a l and two or three foramina of the l e s s e r   p a l a t i n e   c a n a l s. These foramina link the oral cavity with the pterygopalatine fossa (Fig. 57). These canals serve as passages for nerves and blood vessels.
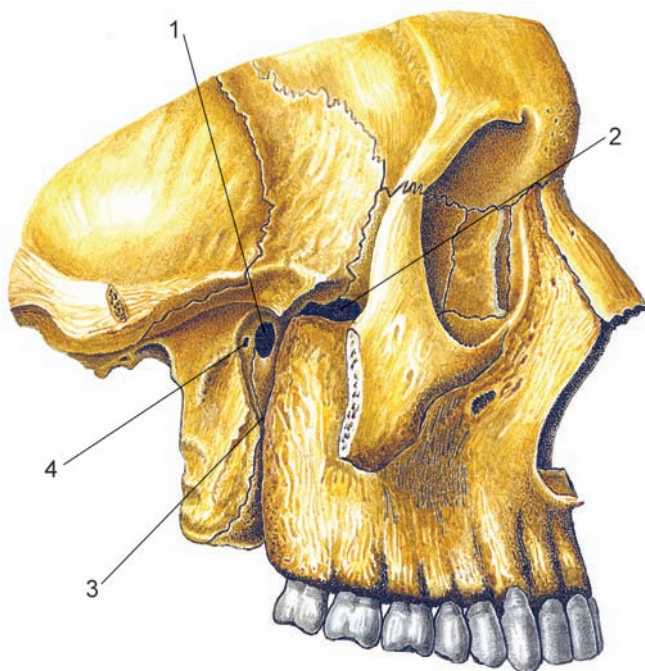
Fig. 57. Pterygopalatine fossa, (zygomatic bone partially removed).

1 — sphenopalatine foramen; 2 — pterygoid canal; 3 — greater palatine canal; 4 — pterygo-palatine fossa.

Table 1. External foramina of the skull base.

Foramen	Structures passing through the foramen		
	Arteries	**Veins**	**Nerves**
Ovale	Accessory (meningeal) branch of middle meningeal artery	Venous plexus of foramen ovale (connects the petrosal sinus with the pterygoid plexus)	Mandibular nerve—third branch of trigeminal nerve
Spinosum	Middle meningeal artery — branch of maxillary artery	Middle meningeal veins (into the pterygoid plexus)	Meningeal branch of maxillary nerve
External aperture of the tympanic canaliculus	Inferior tympanic artery—branch of ascending pharyngeal artery		Tympanic nerve—branch of glossopharyngeal nerve
Caroticotympanic canaliculi	Caroticotympanic arteries (branches of internal carotid artery)		Caroticotympanic nerves—branches of carotid plexus and tympanic nerve
External carotid	Internal carotid artery		Internal carotid plexus
Stylomastoid	Stylomastoid artery — branch of posterior auricular artery	Stylomastoid vein (into the retromandibular vein)	Facial nerve
Tympanosquamous fissure	Deep auricular artery — branch of maxillary artery		
Petrotympanic fissure	Anterior tympanic artery — branch of maxillary artery	Tympanic veins — into retromandibular vein	Chorda tympani — branch of facial (VII) nerve
Mastoid (canaliculus)			Auricular branch of vagus (X) nerve
Mastoid	Meningeal branch of occipital artery	Mastoid emissary vein (connects sigmoid sinus with occipital vein)	
Jugular	Posterior meningeal artery—branch of ascending pharyngeal artery	Jugular vein	Glossopharyngeal (IX), vagus (X) and accessory (XI) nerves; meningeal branch of vagus nerve
Hypoglossal canal		Venous plexus of hypoglossal canal (into jugular vein)	Hypoglossal nerve (XII)

| Condyloid | | Condylar emissary vein (connects the sigmoid sinus with the vertebral venous plexus) | |
| Foramen magnum | Vertebral artery; anterior and posterior spinal arteries | Basilar plexus | Medulla oblongata |

Table 2. Internal foramina of the skull base.

Foramen	Structures passing through the foramen		
	Arteries	**Veins**	**Nerves**
Anterior cranial fossa			
Ethmoid foramina	Anterior ethmoidal artery—branch of ophthalmic artery	Ethmoid veins (into superior ophthalmic vein)	Olfactory nerves (I)
Middle cranial fossa			
Optic canal	Ophthalmic artery		Optic nerve (II)
Superior orbital fissure	Anterior meningeal branch of anterior ethmoid artery	Superior orbital vein (into superior petrosal sinus)	Oculomotor (III), trochlear (IV) and abducent (VI) nerves; ophthalmic nerve—first branch of trigeminal nerve
Internal carotid	Internal carotid artery	Venous plexus of carotid canal	Internal carotid (sympathetic) plexus
Rotundum			Maxillary nerve—second branch of trigeminal nerve
Ovale	Accessory (meningeal) branch of middle meningeal artery	Venous plexus of foramen ovale (connects the petrosal sinus with the pterygoid plexus)	Mandibular nerve—third branch of trigeminal nerve
Spinosum	Middle meningeal artery—branch of maxillary artery	Middle meningeal veins (into the pterygoid plexus)	Meningeal branch of maxillary nerve
Fissure for greater petrosal nerve	Petrosal branch of middle meningeal artery	Auditory vein (into superior petrosal sinus)	Greater petrosal nerve—branch of the facial (intermediate) nerve
Fissure for lesser petrosal nerve (superior aperture of tympanic canaliculus)	Superior tympanic artery—branch of the middle meningeal artery		Lesser petrosal nerve—branch of the tympanic nerve (from glossopharyngeal (IX) nerve).

Posterior cranial fossa			
Internal auditory meatus	Artery of the labyrinth—branch of the basilar artery	Veins of the labyrinth (into inferior petrosal sinus)	Facial (VII) and vestibulocochlear (VIII) nerves
External opening of vestibular aqueduct		Endolymphatic duct and saccule	
External opening of cochlear canaliculus		Perilymphatic duct (into superior bulb of internal jugular vein); vein of cochlear canal	
Mastoid foramen	Meningeal branch of occipital artery	Mastoid emissary (connects the sigmoid sinus with occipital vein)	
Jugular	Posterior meningeal artery—branch of ascending pharyngeal artery	Internal jugular vein	Glossopharyngeal (IX), vagus (X) and accessory (XI) nerves; meningeal branch of vagus nerve
Foramen magnum	Vertebral artery; anterior and posterior spinal arteries	Basilar plexus	Medulla oblongata
Hypoglossal canal		Venous plexus of hypoglossal canal (into internal jugular vein)	Hypoglossal nerve (XII)
Condyloid		Condylar emissary (connects the sigmoid sinus with the vertebral venous plexus)	

SKULL OF A NEWBORN

The skull of a newborn has certain significant peculiarities. The volume of the cranial skull is eight times greater than that of the facial, due to its active growth before birth (the volume of an adult cranial skull is only twice as large as the facial). It is typical for a skull of a newborn to have large orbits, no supraciliary arches, underdeveloped jaws and well-developed frontal and parietal tubers. In a newborn the base of the skull is developing slower than its roof, and gaps between bones are filled with connective tissue membranes.

One characteristic of a skull of a newborn is the presence of fontanels (Fig. 58).
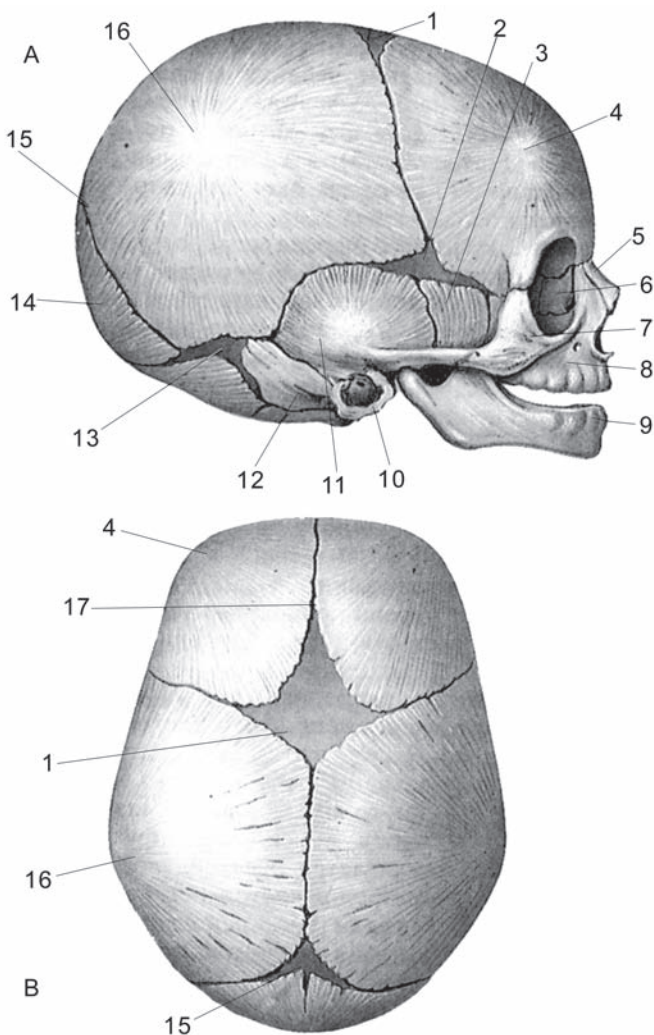
Fig. 58. Cranium of newborn. Lateral aspect (A) and superior aspect (B).

1 — anterior fontanelle; 2 — sphenoidal fontanelle; 3 — greater wing of sphenoidal bone; 4 — frontal tuber; 5 — nasal bone; 6 — lacrimal bone; 7 — zygomatic bone; 8 — maxilla; 9 — mandible; 10 — tympanic ring of temporal bone; 11 — squamous part of temporal bone; 12 — lateral part of occipital bone; 13 — mastoid fontanelle; 14 — squamous part of occipital bone; 15 — posterior fontanelle; 16 — parietal tuber; 17 — frontal suture.

F o n t a n e l s (fontículi) are the membranous areas between incompletely ossified bones. They aid in leveling the pressure inside the skull while the encephalon is undergoing rapid growth during the prenatal peri-

od. The largest one is the diamond shaped a n t e r i o r (f r o n t a l) f o n t a n e l (fontículus frontális). It is located between the right and left sections of the frontal bone and the two parietal bones. It usually closes during the second year of life. The p o s t e r i o r (o c c i p i t a l) f o n t a n e l (fontículus occipitális) is triangular. It is located between the two parietal bones and the squama of the occipital bone in the back. It becomes ossified approximately two or three months after birth. There are two s p h e n o i d a l f o n t a n e l s (fontículus sphenoidális), which are situated at the junction of the frontal and parietal bones, the greater wing of the sphenoid bone and the squama of the temporal bone. The paired m a s t o i d f o n t a n e l (fontículus mastoídeus) is located between the occipital squama and the temporal and parietal bones. Usually the sphenoid and mastoid fontanels begin to close about two or three months after birth, but sometime as early as the last week before birth. Sutures between bones of the skull of a newborn are not completely developed and borders of the bones are smooth.

MODIFICATIONS OF THE SKULL AFTER BIRTH

The development and growth of the skull after birth can be divided into three stages. Starting at birth, until approximately age seven, the skull grows rapidly, especially in the occipital region. During the first year of life the thickness of its bones increases three-fold, and external and internal plates begin to form (appearance of diploe) in bones of the calvaria. Ossification points of growing bones begin to merge and the mastoid process develops. By 5 years of age the bone part of the external auditory canal is completely formed. By age seven the right and left halves of the frontal bone merge and parts of the ethmoid bone become fused together.

Between age seven and puberty /12–13 years/ development of the skull slows down and becomes more even, especially in its base. Growth of the calvaria is reasonably fast.

After age 12–13 and until ages 20–25 there is an intensive growth of the facial skull and sexual characteristics begin to appear.

After ages 20–30 cranial sutures turn into synostosis. The sagittal suture begins to close at the age of 22–35; the coronal suture /its middle part/ fuses during ages 24–41; the lambdoidal suture—at the age of 26–42. The squamous suture rarely fuses completely. The process of suture synosteosis varies between individuals. The unevenness and difference in timing of suture fusion is the main cause of asymmetry of the skull.

During old age the mass of the skull and its elastic quality tend to decrease. The outlining of the skull is less distinct. The facial section short-

ens, the alveolar arches diminish and the angle between the body and rami of the mandible become obtuse.

SEXUAL CHARACTERISTICS OF THE SKULL

Variations between the male and female skulls are relatively few, therefore it is sometimes difficult to distinguish one from the other. The internal relief of a male skull (protuberances and grooves) is more distinctly expressed than that of a female one, which is correlated with the development of muscles of the head. A male skull has larger orbits and more developed paranasal sinuses. The average volume of a male skull is larger than that of a female one due to a greater size of a male body.

DEVELOPMENT OF THE HUMAN SKULL

The cranial skull develops from mesenchymal tissue, surrounding the encephalon. Mesenchymal tissue turns into a connective tissue membrane (stage of the membranous skull). In the region of the calvaria the membranous skull becomes replaced directly with bone tissue (osseous stage), while in the base first comes formation of cartilage tissue (cartilage stage), and then bone tissue. Small areas of cartilage tissue called synchondroses can remain in the skull of an adult for a long time, especially in its base.

Mesenchymal tissue between branchial recesses contains cartilaginous branchial arches (Fig. 59). The first two of these are called visceral arches. Later they develop into the facial skull. The first visceral arch forms the malleus
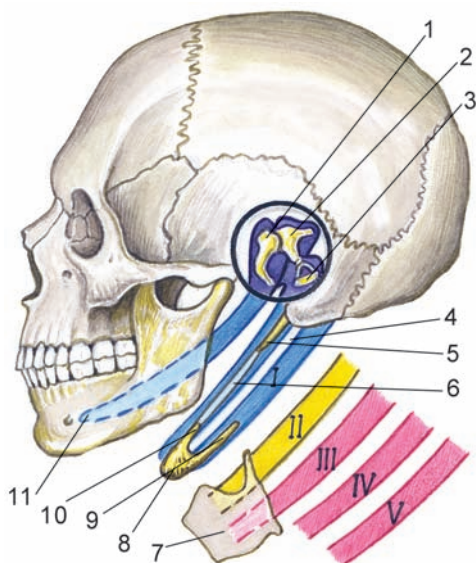

Fig. 59. Location of visceral and branchial arches (I-V) and its derivations (scheme; modified by A.Bistrov)

1 — malleus; 2 — incus; 3 — stapes; 4 — hyoid (II visceral) arch; 5 — styloid process; 6 — stylohyoid ligament; 7 — thyroid cartilage; 8 — body of hyoid bone; 9 — greater horn of hyoid bone; 10 — lesser horn, 11 — Meckel s mandibular cartilage.

(hammer) and incus (anvil), which are ossicles of the tympanic cavity, and the Meckel cartilage, which forms the base of the mandible. The second visceral (hypoglossal) arch forms the stapes (stirrup), an ossicle of the tympanic cavity; the styloid process of the temporal bone and the lesser horns of the hyoid bone. The body and greater wings of the hyoid bone are formed from material of the third arch (the first branchial arch).

Main stages of development of individual bones:

The frontal bone begins to develop from membranous tissue during week 9 of fetal development. The first ossification points appear in the areas of future frontal protuberances. The right and left halves of the frontal bone fuse together between approximately ages 2–7.

The sphenoid bone has a very complicated structure. Its main parts undergo a cartilage stage, while the medial plates of the pterygoid process (except the hamulus), the lateral parts of the greater wings and the sphenoidal conchae go through intramembranous development. The first ossification points appear by week 9 of prenatal development. At birth the sphenoid bone consists of three parts: the body with the lesser wings, the greater wings with the lateral plates of the pterygoid processes and the medial plates of the pterygoid processes. These parts fuse together between the third and eighth years of life.

The occipital bone. All parts of this bone undergo three stages of ossification, which means that they develop on a cartilage model. Ossification points appear during weeks 8–10 of prenatal development and fuse into one bone between the third and fifth years of life.

The parietal bone develops from membranous tissue. First points of ossification appear in places of future parietal protuberances during week 8 of prenatal development.

The ethmoid bone develops from the cartilage olfactory capsule from three points of ossification: one middle and two lateral points. The middle point forms the perpendicular plate; the lateral points form the ethmoidal labyrinths. These structures fuse into one bone during the sixth year of life.

The temporal bone has a complicated structure. The pyramids develop based on a cartilage model. Its ossification points appear by month 5–6 of prenatal life. The squamous and tympanic portions begin to form from membranous tissue during weeks 9–10. The styloid process forms from the second visceral arch. Fusion of parts of the temporal bone begins just after birth and is complete by approximately age 13.

The maxilla is formed on a membrane model, starting on the second month of prenatal development.

Small bones of the facial skull: the vomer palatine, nasal, lacrimal and zygomatic bones, form starting with one or two points of ossification

during the 2–3 months of fetal development. The inferior nasal concha, as well as the ethmoid bone, forms on the base of cartilage of the olfactory capsule.

The m a n d i b l e forms from connective tissue surrounding Meckel's cartilage. At first it consists of two symmetrical halves. Each of these halves contains several ossification points starting at month 2 of prenatal development. As these points gradually fuse together, the cartilage resolves. The two halves grow into one bone between ages 1–2.

The h y o i d b o n e forms out of the second visceral arch (its body and lesser horns) and the first brachial arch (the greater horns). Ossification points appear in the greater horns just before birth, and in the lesser horns between ages 1–2. Fusion of separate bone parts into one bone takes place at ages 25–30.

VARIANTS AND ANOMALIES IN DEVELOPMENT OF THE BONES OF THE SKULL

Variants and anomalies in structure of bones appear when something goes wrong in the process of ossification. The following are the most typical variants.

F r o n t a l b o n e. In about 10 percent of cases the two halves of the frontal bone do not fuse and a frontal (metopic) suture remains between them. The frontal sinus can vary in size, or can be completely absent.

S p h e n o i d b o n e. Sometime the anterior and posterior parts of its body do not fuse, and a narrow craniopharyngeal canal forms as a result. The foramen ovale and foramen spinosum can be of equal size or can fuse into one. The degree of pneumatisation varies between individuals.

O c c i p i t a l b o n e. The superior part of the bone may not fuse with the rest of the bone and remains separated from it by a transverse suture. As a result there is an individual interparietal bone. Sometimes the occipital condyles partially or completely fuse with the first cervical vertebra (atlas assimilation). Frequently there are small bones located around the occipital bone called sutural (Wormian) bones. Sometimes the external occipital protuberance is highly developed and appears like a process.

E t h m o i d b o n e. The shape, number and sizes of the ethmoidal air cells can vary. Sometimes there is a suprema nasal concha.

P a r i e t a l b o n e can have superior and inferior parts.

T e m p o r a l b o n e. An interjugular process can divide the jugular notch. The styloid process can be absent or can be considerably lengthened as a result of ossification of the stylohyoid ligament.

M a x i l l a. In the region of the palatine processes there is sometimes an unpaired incisive bone. The incisive canal and maxillary sinuses can vary

between individuals. Cleft palate /palatoschisis/ is the most drastic anomaly of the maxilla; it appears when the palatine processes do not fuse together.

Z y g o m a t i c b o n e. Frequently the number and passage of the canals penetrating the zygomatic bone can vary. The foramina on the surface of the bone vary in size and form.

N a s a l b o n e. The shape and size of this bone may vary individually. Sometimes this bone is not present at all, but is replaced by the frontal process of the maxilla.

L a c r i m a l b o n e. Its shape and size are inconstant, or it may be completely absent.

T h e i n f e r i o r n a s a l c o n c h a and its processes vary in shape and sizes.

T h e v o m e r can be deviated to the right or left, leading to an asymmetrical nasal cavity.

M a n d i b l e. Its right and left halves are frequently asymmetrical, and sometimes are not completely fused. Sizes of the mandibular angle can have individual and age differences.

H y o i d b o n e. The size and shape of this bone and the length of its processes are not constant.

Questions for revision and examination

1. Describe the boundaries and walls of the temporal, infratemporal and pterygopalatine fossae.
2. Name the foramina found on the external cranial base.
3. Name the boundaries and walls of the cranial fossae on the internal surface of the base of the skull and the foramina found in these fossae.
4. Describe the walls and foramina of the orbit.
5. What bones form the walls of the nasal cavity? What are the nasal conchae and nasal meatuses?
6. Describe the characteristic properties of the skull of a newborn.
7. What do you know about the sexual and age characteristics of the skull?

THE APPENDICULAR SKELETON

The upper extremity serves as an instrument of work, and thus has significant freedom of movement. This is partly determined by the way the clavicle connects it with the axial skeleton, and partly by mobility of junctions between its bones. Much thicker and more massive bones are typical for the lower extremity, the function of which is support and movement. Mobility of joints in the lower extremity is significantly less than in the upper. Bone elements of the upper and lower limbs include the limb girdles and the hanging parts.
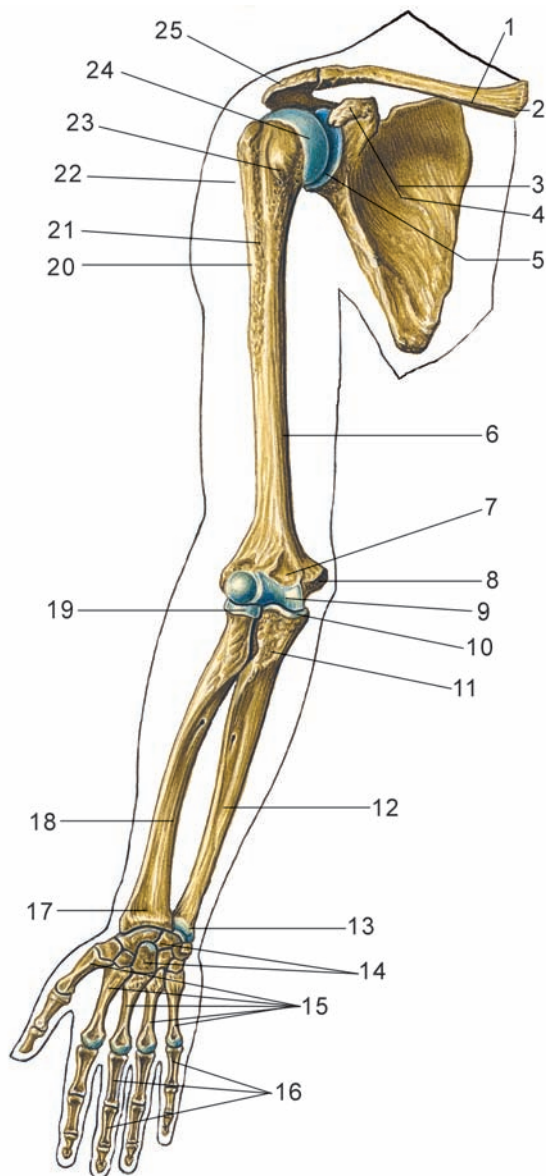
Fig. 60. Bones of upper limb. Anterior aspect.

1 — clavicle; 2 — sternal end of clavicle; 3 — scapula; 4 — coracoid process; 5 — glenoid cavity; 6 — humerus; 7 — coronoid fossa of humerus; 8 — medial epicondyle; 9 — trochlea; 10 — coronoid process; 11 — tuberositas of ulna; 12 — ulna; 13 — head of ulna; 14 — carpal bones; 15 — metacarpals; 16 — phalanges; 17 — styloid process of radius; 18 — radius; 19 — head of radius; 20 — crest of greater tubercle; 21 — intertubercular sulcus; 22 — greater tubercle; 23 — minor tubercle; 24 — head of humerus; 25 — acromion.

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BONES OF THE UPPER EXTREMITIES

The upper limb girdle, or pectoral girdle /cingulum membri superiores/ consists of the clavicle and scapula. The hanging part of the upper limb /pars libera membri superiores/ is divided into three sections. The proximal section is the arm, the middle section is the forearm, and the distal section consists of bones of the hand. The hand consists of carpal and metacarpal bones and phalanges (Fig.60).

The pectoral girdle

The scapula (scápula) is a flat triangular bone, located on the posterolateral thoracic wall. The scapula has three a n g l e s: the i n f e r i o r, l a t e r a l and s u p e r i o r. Between them are three borders: the m e d i a l b o r d e r, which runs parallel to the vertebral column, the lateral, which is directed laterally and down, and the superior border. The s u p e r i o r b o r - d e r has a s u p r a s c a p u l a r n o t c h for passage of nerves and blood vessels. The costal surface of the scapula faces the ribs in the front and has a shallow s u b s c a p u l a r f o s s a.

The dorsal surface of the scapula is convex and has a crest extending backwards called the s p i n e o f s c a p u l a. Above this crest there is a depression called the s u p r a s p i n o u s f o s s a, and below the crest is the i n f r a s p i n o u s f o s s a. These fossae are filled by homonymous muscles. The lateral end of the scapular spine forms a broad flattened process called the a c r o m i o n. On the top of the acromion there is an articular facet, which forms a joint with the clavicle. The broad lateral angle of the scapula forms an articular fossa (g l e n o i d c a v i t y), which articulates with the head of the humerus. Above and below the articular fossa there are, respectively, the s u p r a g l e n o i d and i n f r a g l e n o i d t u b e r c l e s. These tubercles are sites of attachment of muscles of the arm. A curved c o r a c o i d p r o c e s s extends to the front from the upper border of the scapula.

The clavicle (clavícula) is a long curved bone, situated between the acromion and the clavicular notch of the sternum. The clavicle has a body and two e n d s: a c r o m i a l and s t e r n a l. On its inferior surface, closer to the acromial end, there are two tuberocities — the c o n o i d t u b e r c l e and the t r a p e z o i d l i n e — which are attachment sites of ligaments.

Skeleton of the free upper extremities

The humerus (húmerus) is a typical long tubular bone with two ends (epiphyses) and a body, its diaphysis (córpus húmeri). The superior epiphysis is thickened. It forms the h e a d of the humerus (cáput húmeri).

Near the spherical head are the greater and lesser tubercles, which serve for attachment of muscles. The g r e a t e r   t u b e r c l e is situated laterally to the le s s e r   t u b e r c l e. Down from the greater tubercle extends a c r e s t   o f   t h e   g r e a t e r   t u b e r c l e. Between the two tubercles there is an i n t e r t u b e r c u l a r   s u c l u s. In this groove lies the tendon of the long head of the biceps. The thinnest place between the head and the body of the humerus is the s u r g i c a l   n e c k. It is the most frequent site of fractures of the upper end of the humerus. The b o d y of the humerus is cylindrical in its upper half and trihedral in its lower half. Almost halfway down the lateral side of the bone there is a d e l t o i d   t u b e r o s i t y, which is an attachment site for the deltoid muscle. On the posterior surface there is a r a d i a l   g r o o v e spiraling downwards medial to lateral. The large distal end forms the c o n d y l e   o f   t h e   h u m e r u s. The medial part of the condyle called the tr o c h l e a articulates with the ulna. The lateral part, the c a p i t u l u m, articulates with the radius. On the anterior surface of the humerus, above the trochlea, is the c o r o n o i d   f o s s a, and to its lateral one is the r a d i a l   f o s s a. On the posterior surface, above the trochlea is the o l e c r a n o n   f o s s a. On the lateral and medial surfaces, above the condyle there are two protuberances called the l a t e r a l and m e d i a l   e p i c o n d y l e s. On the posterior surface of the medial epicondyle is the g r o o v e   f o r   u l n a r   n e r v e. The epicondyles continue into the m e d i a l and l a t e r a l   s u p r a c o n d y l a r   c r e s t s.

Bones of the forearm

The bones of the forearm are the ulna, situated to the medial, and the radius, situated to the lateral. Between the diaphyses of these bones is the interosseous space of the forearm. The structures of the two bones have many similarities. Each one has three borders, including an interosseous border, which is turned towards the neighboring bone.

Radius (rádius). At the proximal end of the radius its head articulates with the condyle capitulum of the humerus. The h e a d of the radius has a flat depression — its articular facet. Beneath the articulation fossa is the cylindrical n e c k of the radius. On the front medial surface of the bone, above the neck, is the r a d i a l   t u b e r o s i t y. This tuberosity is the site of attachment of the biceps brachii tendon. On the medial side of the distal end of the radius is the u l n a r   n o t c h, and on the lateral side is the s t y l o i d   p r o c e s s. On the inferior side of the distal end is the c a r p a l   a r t i c u l a r   s u r f a c e, which articulates with carpal bones.

Ulna (úlna). The large proximal end of the ulna has a t r o c h l e a r   n o t c h, which articulates with the trochlea of the humerus. This notch ends with two processes. One is the larger posterior ulnar process (o l e -

c r a n o n), and the other, in the front, is the c o r o n o i d   p r o c e s s (procéssus coronoídeus). The latter is shorter than the olecranon and has a radial for articulation with the head of the radius. There is a r a d i a l   t u b e r o s - i t y above the coronoid process, which serves for attachment for muscle. The distal part of the radius ends with its h e a d, which continues medially into a s t y l o i d   p r o c e s s (procéssus styloídeus). The head has a circular a r t i c u l a r c i r c u m f e r e n c e for articulating with the radius.

Bones of the hand

The hand (mánus) consists of the wrist (carpus), metacarpus and phalanges (Fig. 61).
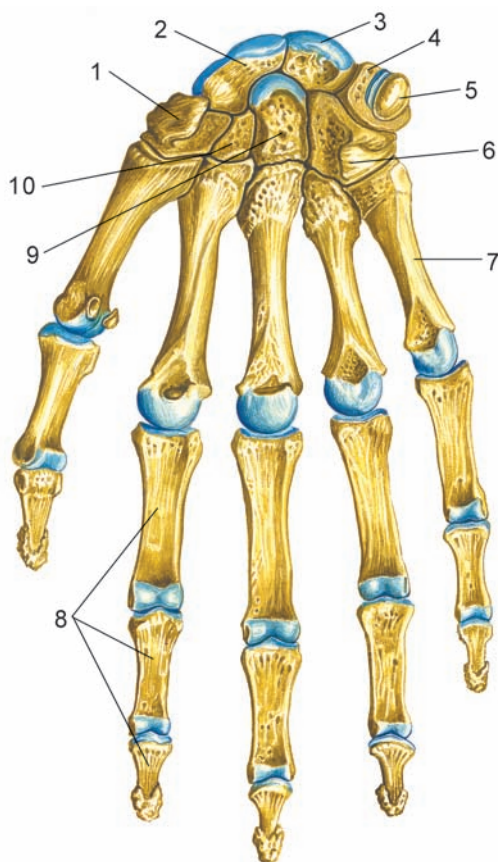

Fig. 61. Bones of hand. Anterior aspect.
1 — trapezium; 2 — scaphoid; 3 — lunate; 4 — triquetrum; 5 — pisiform; 6 — hamate; 7 — carpal bone; 8 — falanges; 9 — capitate; 10 — trapezoid.

The carpus consists of eight spongy bones arranged in two transverse rows. In the proximal row are the s c a p h o i d, l u n a t e, t r i q u e - t r a l, and p i s i f o r m bones. The distal row includes the trapezium (greater polygonal), t r a p e z o i d (lesser polygonal), c a p i t a t e, and h a m a t e. The name of each bone correlates with the shape of the bone. The bones have articular facets for articulation with neighboring bones.

Carpal bones form a bone arch in this part of the hand, which is convex to the back and concave on the palmar side. Because of this there is a carpal groove on the palmar side of the carpus. This groove is limited by the scaphoid and trapezium from the lateral side, and by the hamate and capitate from the medial side.

Metacarpal bones. The metacarpus (metacarpus) is formed by five short tubular bones. Metacarpals are numerated from I-V starting at the thumb. Each metacarpal bone has a b a s e, a b o d y and a h e a d. The bases are joint with the bones of the second transverse row of the carpus. The semispherical heads of metacarpal bones end with convex articular facets, which articulate with bases of the phalanges.

Phalanges. The shortest and thickest digit is the t h u m b (póllex). Next to it are the f o r e f i n g e r (dígitus sécundus), the m i d d l e   f i n g e r (dígitus médius), the r i n g   f i n g e r (dígitus annuláris), which is the longest, and the little finger.

Phalanges (phalánges digitórum) are relatively short tubular bones. Each digit, except for the first one has a proximal middle and distal phalanges. The thumb has only proximal and distal phalanges. The proximal phalanges are the longest, while the distal are the shortest. Each phalanx has a b a s e, a b o d y and a h e a d. The end of each distal phalanx is flat and has a tuberosity of the distal phalanx.

Variants and anomalies of the skeleton of the upper extremities

Scapula. The depth of the scapular notch varies and the notch is sometimes turned into a foramen. A cartilage layer may remain between the acromion and the scapular spine throughout the whole life.

Clavicle. The curvatures of the clavicle vary a lot. Sometimes there is no trapezoid line or coneshaped tubercle.

Humerus. There can be an additional process above the medial condyle. It can be long and curved, forming a foramen.

Ulna and radius. The radius may be absent (rare anomaly). The olecranon sometimes does not fuse with the body of the ulna, with a layer of cartilage remaining between them.
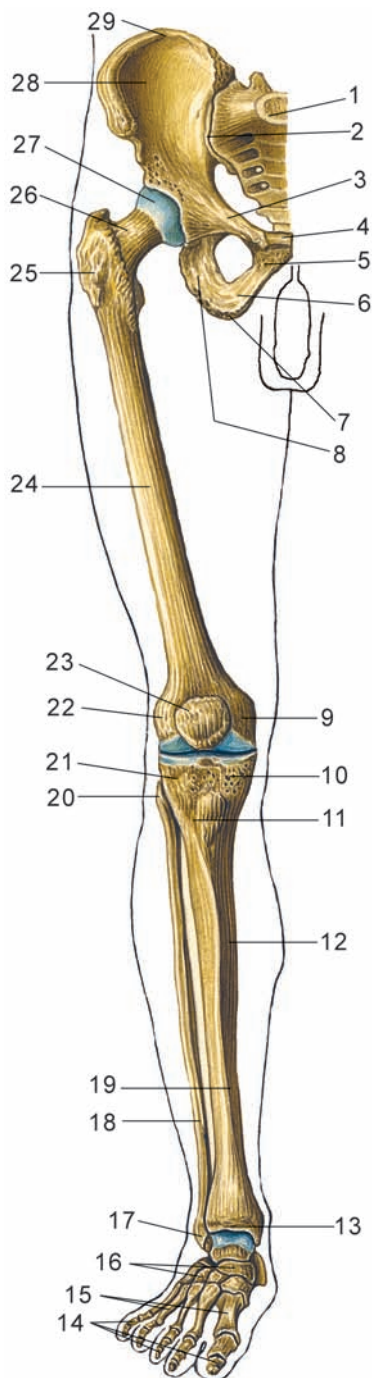
Fig. 62. Bones of lower limb. Anterior aspect.

1 — sacrum; 2 — sacroiliac joint; 3 — superior pubic ramus; 4 — symphysial surface of pubic bone; 5 — inferior pubic ramus; 6 — ramus of ischium; 7 — ischial tuber; 8 — body of ischium; 9 — medial epicondyle of femur; 10 — medial epicondyle of tibia; 11 — tuberositas of tibia; 12 — body of tibia; 13 — medial malleolus; 14 — phalanges; 15 — tarsal bones; 16 — metatarsal bones; 17 — lateral malleolus; 18 — fibula; 19 — anterior margin of tibia; 20 — head of fibula; 21 — lateral epicondyle of tibia; 22 — lateral epicondyle of femur; 23 — patella; 24 — femur; 25 — greater trochanter of femur; 26 — neck of femur; 27 — head of femur; 28 — wing of ilium; 29 — iliac crest.

Bones of the hand. There are sometimes additional carpal bones (central bone, etc.) Sometimes there is a development of additional fingers (polydactyly) or fusing of neighboring fingers.

Questions for revision and examination

1. Name the most prominent regions on bones of the upper extremities: processes, crests, tubercles and tuberosities.
2. Name the articular surfaces of bones of the upper extremities and the joints they form.
3. How many bones are there in the hand? Name them.

BONES OF THE LOWER EXTREMITIES

Whereas bones and joints of the upper extremities are well-suited for handling different objects /instruments of labor/, lower extremities have other functions.

The lower extremities perform functions of support and movement of the body in space. Conforming to these functions, they contain larger

and more massive bones compared to the upper limbs. Joints of the lower extremities are also larger, while their mobility is less.

Skeleton of the lower extremities consists of the pelvic girdle and bones of the free lower extremities (Fig. 62).

The pelvic girdle (cíngulum mémbri inferióris) is formed by paired hipbones, which are joint with each other in the front and are attached to the sacrum in the back. The skeleton of the free part of the upper extremities (skeleton membri inferioris liberi) has three parts. The proximal part is the femur, the middle is formed by the tibia and fibula, and the distal part consists of bones of the foot. The skeleton of the foot is formed by the tarsal and metatarsal bones and phalanges. In the region of the knee joint lies the largest sesamoid bone — the patella.

Bones of the pelvic girdle

The hipbone (os cóxae) is formed as a single bone by fusion of three individual bones: the ilium, pubis and ischium (at the age of 12–14). The bodies of these three bones together form a cotyloid cavity (acetábulum), which is an articular fossa for the head of the femur. On the periphery of the acetabulum is a l u n a t e s u r f a c e, and in its center is the a c e t a b - u l a r f o s s a (Fig. 63).

The i l i a c b o n e (ós íleum) has a thickened lower portion and a broad upper portion, which forms the a l a o f t h e i l i u m. On the top of the iliac wing is a broad i l i a c c r e s t. On the top the iliac crest has three uneven lines, which are the o u t e r l i p, the i n n e r l i p, and the i n t e r - m e d i a t e z o n e between them. These lines serve for attachment of ab- dominal muscles. In the front and back the iliac crest ends with bony prominences. The front one is the a n t e r i o r s u p e r i o r i l i a c s p i n e. Somewhat below it is the a n t e r i o r i n f e r i o r i l i a c s p i n e. In back the ileac crest ends with the posterior superior iliac spine, below which is the p o s t e r i o r i n f e r i o r i l i a c s p i n e. On the dorsolateral surface of the iliac wing there are three uneven lines. These are the a n t e r i o r, p o s t e r i o r and i n f e r i o r g l u t e a l l i n e s, which are attachment sites for the gluteal muscles and their fasciae.

On the concave surface of the wing of the ilium there is a slight recess called the i l i a c f o s s a. At the bottom the iliac fossa is limited by an arched line. At the back this line extends to the a u r i c u l a r s u r f a c e, and in the front it continues into the i l i o p u b i c e m i n e n c e. Above the auricular surface is the i l i a c t u b e r o s i t y, which serves for attach- ment of ligaments.

The p u b i c b o n e (ós púbis) has a b o d y (a thickened portion) and two rami. The pubic bone body forms the anterior portion of the ace- tabulum. The s u p e r i o r r a m u s of the pubis extends forward from the

B

A

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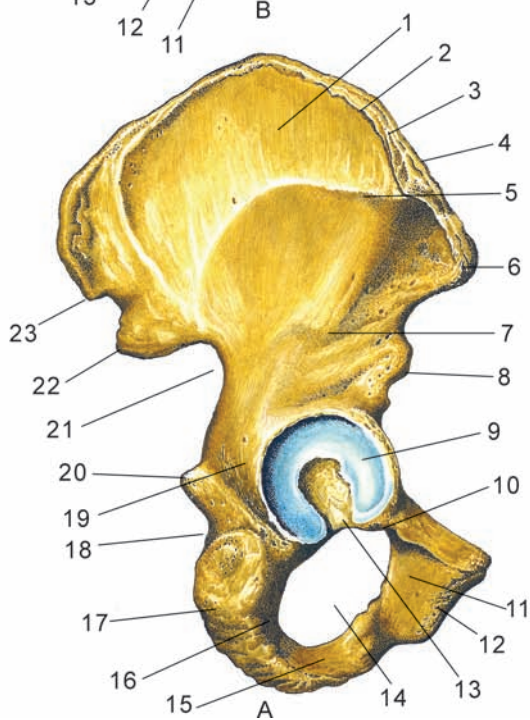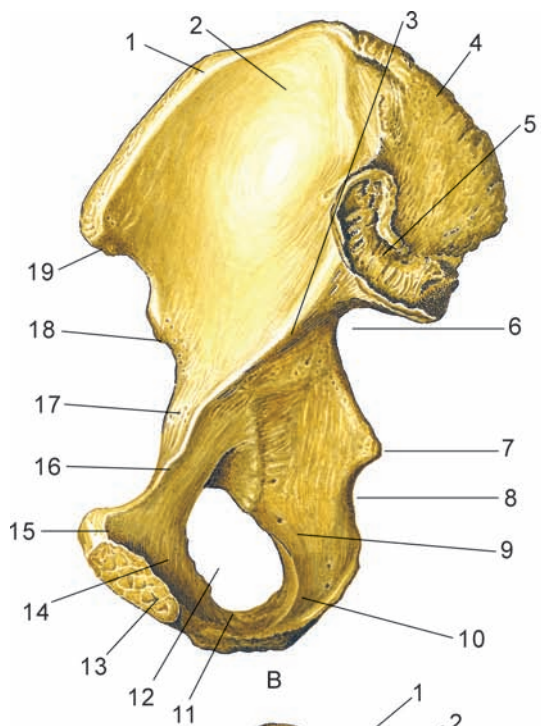
body. In the region of the body the bone makes a sharp turn and continues into the i n f e r i o r r a m u s of the pubis. On the superior ramus there is a p u b i c t u b e r c l e. Below the tubercle is a flat s y m p h y s i a l s u r - f a c e, which serves for joining the pubic bone with its pair.

The b o d y of the i s c h i a l b o n e (ós íschii) forms the inferior portion of the acetabulum. The r a m u s of the ischium extends downwards from the body, forming a thickening called the i s c h i a l t u b e r - o s i t y. The i s c h i a l s p i n e, located on the body of the ischium, separates the g r e a t e r and l e s s e r s c i a t i c n o t c h e s. The ramus of the ischium is fused with the inferior ramus of the pubis, limiting the o b t u - r a t o r f o r a m e n (forámen obturátum). On the superior anterior border of this foramen is the o b t u r a t o r g r o o v e.

Skeleton of the free lower extremity

The femur (fémur) is a typical long tubular bone with an elongated body and two thickened ends. Its proximal end is rounded and forms the h e a d o f t h e f e m u r (cáput fémoris) for the joint with the hipbone. Below the head is the n e c k o f t h e f e m u r. At the boundary between the neck and the body there are two prominences — the greater and lesser trochanters.

The g r e a t e r t r o c h a n t e r (trochánter májor) is located at the top on the lateral side. The l e s s e r t r o c h a n t e r (trochánter mínor) is situated medially and to the back. The two trochanters are connected in the front by the i n t e r t r o c h a n t e r i c l i n e, and in the back by the i n t e r t r o c h a n t e r i c c r e s t. The b o d y o f t h e f e m u r (córpus fémoris) has an almost cylindrical s h a p e. On its posterior surface there is a linea aspera, which diverges at the top and bottom, forming m e d i a l and l a t e r a l l i p s. At the top the medial labium passes into the p e c t i n e a l l i n e, and the lateral labium ends as the g l u t e a l t u - b e r o s i t y, which serves for attachment of the gluteus maximus muscle.

Fig. 63. Pelvic bone, right.

A — external surface: 1 — ilium; 2 — outer lip; 3 — intermediate zone; 4 — inner lip; 5 — anterior gluteal line; 6 — superior anterior iliac spine; 7 — inferior gluteal line; 8 — inferior anterior iliac spine; 9 — lunate surface; 10 — obturator crest; 11 — obturator groove; 12 — inferior pubic ramus; 13 — acetabular notch; 14 — obturator foramen; 15 — ramus of ischium; 16 — body of ischium; 17 — ischial tuberosity; 18 — lesser sciatic notch; 19 — ishium; 20 — ischial spine; 21 — greater sciatic notch; 22 — posterior inferior iliac spine; 23 — posterior superior iliac spine.

B — internal surface: 1 — iliac crest; 2 — iliac fossa; 3 — terminal line; 4 — iliac tuberosity; 5 — auricular surface; 6 — greater sciatic notch; 7 — ischial spine; 8 — lesser sciatic notch; 9 — body of ischium; 10 — ramus of ischium; 11 — inferior ramus of pubic bone; 12 — obturator foramen; 13 — symphysial surface; 14 — superior pubic ramus; 15 — pubic tubercle; 16 — pubic crest; 17 — iliopubic eminence; 18 — inferior anterior iliac spine; 19 — superior anterior iliac spine.

At the bottom the two diverging labia limit the p o p l i t e a l s u r f a c e. The distal end of the femur is thickened and forms t h e m e d i a l and l a t e r a l c o n d y l e s (c ó n d y l u s m e d i á l i s e t c ó n d y l u s late-r á l i s). The medial condyle is larger than the lateral. Between the condyles in the back there is a deep i n t e r c o n d y l a r f o s s a, and in the front is a slightly concave patellar surface. At the top and to the side the medial condyle continues into the m e d i a l e p i c o n d y l e. Above the lateral condyle is a smaller l a t e r a l e p i c o n d y l e.

The patella (patélla) is the largest sesamoid bone. It has a b a s e at the top and a narrowed a p e x at the bottom. The posterior a r t i c u l a r s u r f a c e of the patella faces the patellar surface of the femur. The anterior surface of the patella is easily palpated through the skin.

Bones of the leg

Bones of the leg include the tibia, or shinbone, located medially, and the fibula, located laterally. Between these bones is the i n t e r o s s e a l s p a c e o f t h e l e g (spátium interósseum crúris). These are both long tubular bones. Each has a diaphysis and two epiphyses.

The tibia (tíbia) is the larger bone of the leg. Its proximal end has two thickenings on which are the m e d i a l and l a t e r a l c o n d y l e s. The upper portions of both condyles form the s u p e r i o r a r t i c u l a r s u r f a c e for the joint with the femur. Between the two condyles, on the surface of the articular surface, there is i n t e r c o n d y l a r e m i n e n c e. This eminence has medial and lateral i n t e r c o n d y l a r t u b e r c l e s, to which the cruciform ligaments of the knee joint are attached. To the lateral and below the laterral condyle is the f i b u l a r a r t i c u l a r f a c e t.

The b o d y o f t h e t i b i a has a trihedral shape with m e d i a l, l a -t e r a l and p o s t e r i o r s u r f a c e s. On the upper part of the posterior surface there is an oblique s o l e a l l i n e of the soleus muscle. The body of the bone also has three borders. The a n t e r i o r b o r d e r is the most acute and can be easily palpated through the skin. In its upper portion it is thickened and forms the t i b i a l t u b e r o s i t y, which is an attachment site for the tendon of the quadriceps of the femur. The i n t e r o s s e o u s b o r d e r of the tibia is on its lateral side, and confines the interosseous space of the leg. The m e d i a l b o r d e r of the bone is rounded.

On the thickened distal epiphysis of the tibia, on the lateral side, there is a f i b u l a r n o t c h. A flattened process called the m e d i a l m a l l e o -l u s (malleólus mediális) extends medially at the bottom of the tibia. On the lateral side of the malleolus is an a r t i c u l a r s u r f a c e, situated at an angle to the i n f e r i o r a r t i c u l a r s u r f a c e of the tibia.

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The fibula (fíbula) has almost the same length as the tibia, but is significantly thinner. The proximal end of the fibula forms its h e a d. On the medial side of the head there is an a r t i c u l a r f a c e t for articulation with the tibia. Beneath the head the bone narrows, passing into its neck and then its b o d y. The medial, or i n t e r o s s e o u s, b o r d e r of the fibula confines from this side the interosseous space of the crus. The distal end of the fibula is thickened and forms the l a t e r a l m a l l e o l u s (malleólus laterális), on the inner surface of which is an articular surface.

Bones of the foot

The foot (pes) is divided into the tarsus, metatarsus and the phalanges.

The tarsal bones include seven spongy bones. These are the t a l u s and c a l c a n e u s, located in the proximal row, and bones of the distal row: the n a v i c u l a r, c u b o i d a l and m e d i a l, i n t e r m e d i a t e and l a t e r a l c u n e i f o r m b o n e s (Fig. 64).

The talus (talus). This bone has a h e a d, extending to the front, a b o d y and a neck. On the top of the body is the t r o c h l e a o f t a l u s, the s u p e r i o r f a c e t of which articulates with the inferior articular surface of the tibia. At the sides of the trochlea are the m e d i a l and l a t e r a l m a l l e o l a r f a c e t s, which articulate with homonymous malleoli of the tibia and fibula. Beneath the lateral malleolar surface is the l a t e r a l p r o c e s s of the talus. On the inferior side of the talus are the a n t e r i o r, middle and p o s t e r i o r c a l c a n e a l a r t i c u l a r f a c e t s. Between
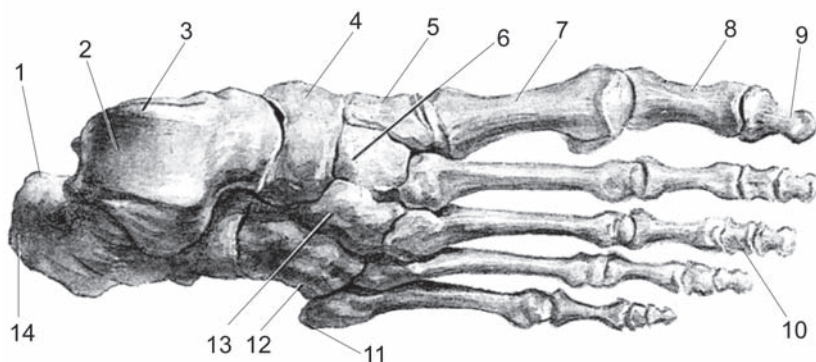

Fig. 64. Bones of foot. Superior aspect.

1 — calcaneus; 2 — trochlea of talus; 3 — talus; 4 — navicular; 5 — middle cuneiform; 6 — intermediate cuneiform; 7 — I metatarsal bone; 8 — proximal phalanx; 9 — distal phalanx; 10 — middle phalanx; 11 — tuberositas V metatarsal bone; 12 — cuboid; 13 — lateral cuneiform; 14 — tuber of calcaneus.

the middle and the posterior surfaces there is a deep groove of the talus (c u l c u s   t a l i).

The calcaneus (calcáneus), the largest bone of the tarsus, is located under the talus. In the back the body of the calcaneus ends with a pronounced c a l c a n e a l tiberósity. The superior surface has an anterior and m i d d l e t a l a r a r t i c u l a r s u r f a c e s for the talus, between which is a c a l c a n e a l s u l c u s. On the back of the body is the p o s t e r i o r a r t i c u l a r t a l a r s u r f a c e for the talus. On the superior anterior border of the bone there is a thick short process called the s u s t e n t a c u l u m t a l i of calcaneus. On the lateral surface there is a longitudinal g r o o v e f o r t h e t e n d o n o f t h e f i b u l a r i s l o n g u s. On the front of the head of the calcaneus there is a cuboid articular surface.

The navicular bone (os naviculáre) is flattened and lies between the talus and the cuneiform bones.

The cuneiform bones (ossa cuneiformia). The medial, intermediate and lateral cuneiform bones are located in front of the navicular bone. They are situated in the medial portion of the tarsus.

The cuboid bone (os cuboídeum) lies in front of the calcaneus. It is situated in the lateral portion of the tarsus.

Metatarsal bones (óssa metatársi). The skeleton of the metatarsus is formed by five short tubular bones. These bones are numerated I–V starting at the big toe. Each metatarsal bone has a base, a body and a head. The bases of metatarsal bones are connected with bones of the tarsus. The heads of these bones have a semispherical shape with convex articular surfaces for joints with bases of the phalanges.

Phalanges of the foot (óssa digitórum pédis) are significantly shorter and thicker then the fingers of the hands. All toes, except for the first one, consist of three p h a l a n g e s: a p r o x i m a l, a m i d d l e and d i s t a l. The big toe (hallux) has only proximal and distal phalanges. Phalanges are short tubular bones, each one composed of a base, a body and a head.

Variants and anomalies of the skeleton of lower extremities

The hipbone. Sometimes the iliac bone can be very elongated. The thickness of the iliac crest and the length of the ischial spine may significantly vary.

The femur. Often the gluteal tuberosities have the appearance of a process (a third trochanter).

Bones of the leg. The shape of the tibiae may be flattened. Sometimes the malleoli are underdeveloped.

Bones of the foot. Sometimes there are additional tarsal bones. Additional digits can develop on the foot as well as on the hand. Neighboring toes may fuse together.

1. Name the prominences (tuberosities, processes, lines) found on the hipbone, femur tibia and fibula, which serve as sites of beginning and attachment of muscles.
2. Name the articular surfaces of bones of the lower extremity. What joint does each surface participate in?
3. How many bones compose the skeleton of the foot. Name these bones.
4. On the surfaces of which bones are there grooves created by adjoining tendons? What are these grooves called?

JOINTS

Joints are part of the support and locomotion apparatus. They retain bones close to each other and provide their mobility during various movements.

CLASSIFICATION OF JOINTS

All joints are subdivided into three large groups: continuous articulations, symphyses and discontinuous (synovial) joints.

Continuous articulations can be formed by different kinds of connective tissue (Fig. 65).
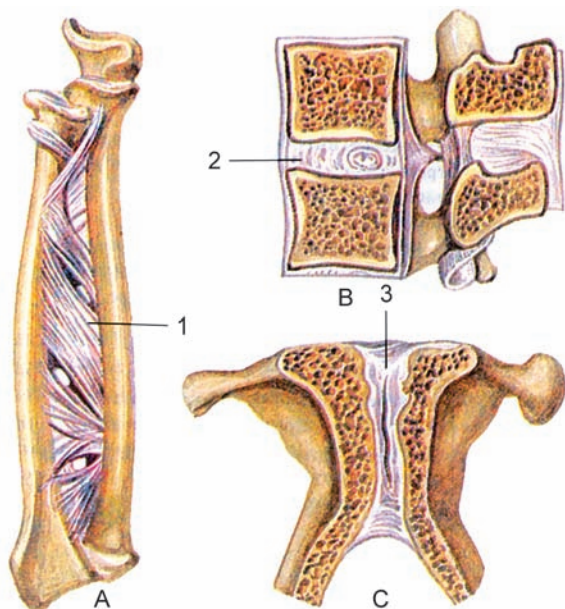

Fig. 65. Synostosis and semi-joint.

A — syndesmosis: 1 — interosseus membrane of forearm; B — synchondrosis: 2 — intervertebral disk; C — symphisis (secondary cartilaginous joint): 3 — pubic symphisis.

They can be fibrous, cartilaginous and bony. **Fibrous joints (junctúra fibrosa)** include sutures, gomphoses and syndesmoses. **Sutures (suturae)** are joints between bones of the skull, made up of thin layers of connective tissue. There are three kinds of sutures, depending on the shape of the bone edges involved. **P l a n e (h a r m o n i c)** s u t u r e s are found in the facial skull, where edges of bones are straight. S e r r a t e s u t u r e s are formed between bones with jagged edges. They are found in the cranial portion of the skull. An example of a s q u a m o u s s u t u r e is the junction between the squamae of the temporal and parietal bones. Sutures provide amortization of impacts and concussions during walking, jumping, etc. Sutures also serve as zones of bone growth. After age 40–50 many sutures become fused (synosteotic). Premature fusion of sutures can result in deformation of the skull. Asynchrony of suture fusion, particularly of paired sutures, is the main reason for asymmetry of the skull. A g o m p h o s i s is a connective fiber joint between the root of a tooth and walls of a dental alveolus.

Syndesmoses are connections created by ligaments and interosseous membranes. Neighboring bones are connected by ligaments in the form of thick bundles of compact connective tissue. These ligaments strengthen the joints, directing and restricting their movement. The majority of ligaments is formed by collagen fibers. Ligamenta flava, which join the arches of adjacent vertebrae, are composed of elastic fibers. Ligaments collagen fibers have little tensility and high strength. Interosseous membranes are found between diaphyses of tubular bones. They provide mobility of the connected boned relative to each other, and can serve as places of the beginning of muscles.

Articulations formed by cartilage tissue are called cartilaginous joints, or synchondroses (junctúra cartiláginea, s. synchondrósis). These joints have considerable strength and elasticity due to high elastic properties of cartilage. They are subdivided into constant synchondroses, which exist throughout life (e.g. intervertebral diskc), and temporary synchondroses, which become replaced at a certain age by bone tissue (e.g. epiphyseal cartilage of tubular bones).

Bony adhesions (synostoses) are formed as a result of substitution of synchondroses by bone tissue. An example of synostosis is the substitution of cartilage between pubic, iliac and ischial bones by bony tissue and formation of the hipbone.

Cartilaginous joints also include **symphyses (semi-joints)**, which consist of a layer of cartilage between bones with a narrow slit-like cavity inside. Thus, symphyses occupy an intermediate position between continuous and discontinuous joints. An example of this kind of articulation is the pubic symphysis.

Synovial joints (articulatio, s. articulationis synovialis) are discontinuous joints (Fig. 66). They are typically formed by cartilage-covered articular surfaces, an articular capsule, and a joint cavity, filled with synovial fluid. In addition some joints may have formations such as an articular disk, a meniscus, or an articular labrum.

A r t i c u l a r   s u r f a c e s can be complementary (congruent) to each other, or may have different shape and size (be incongruent). A r t i c u l a r   c a r t i l a g e (cartilágo articuláris) is generally hyaline. Fibrous articular cartilage can be found only in the temporomandibular and sternoclavicular joints. The thickness of articular cartilage varies from 0.2 to 6 mm. Under mechanical loads it becomes flattened, and acts like a spring due to its resilience (Fig.67).
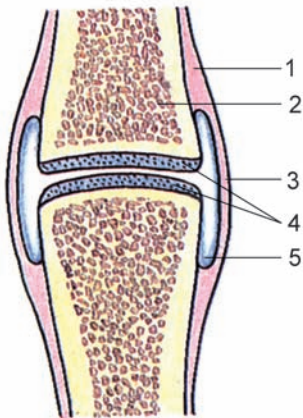
Fig. 66. Structure of joint.
1 — periosteum; 2 — bone; 3 — joint capsule; 4 — epiphysial cartilage; 5 — articular cavity.
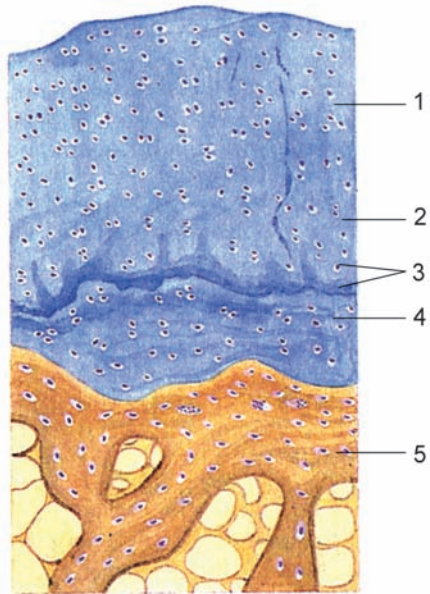
Fig. 67. Transverse section of articular cartilage.
1 — superficial layer; 2 — cartilaginous basic substance; 3 — profound layer (groups of chondrocytes); 4 — cartilage, brandied with Ca; 5 — bone.

The a r t i c u l a r   c a p s u l e (cápsula articuláris) is attached to the edges of the articular cartilage or at some distance from it. It accretes firmly with the periosteum, forming a closed a r t i c u l a r   c a v i t y, the pressure inside which is maintained below atmospheric. The capsule is
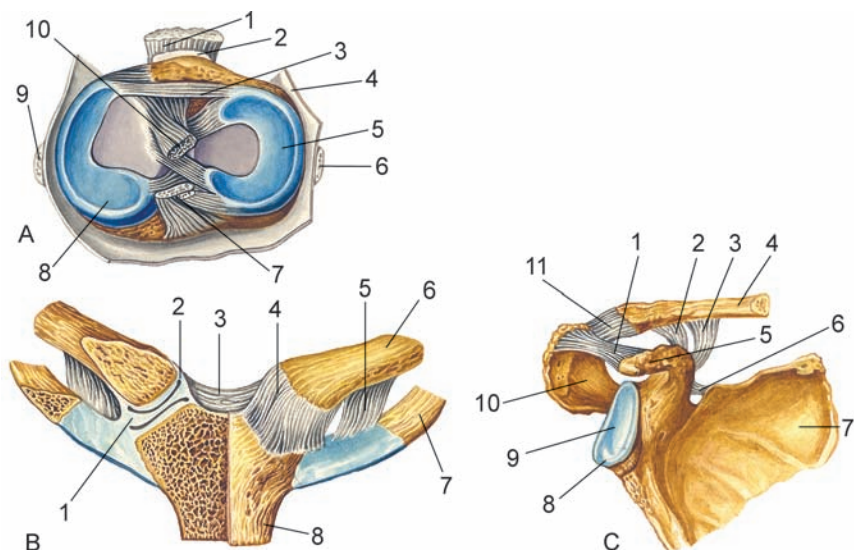
Fig. 68. Types of joints, which have additional formations.

A — knee joint, right; on a horisontal section articular capsule and cruciformial ligaments are clearly evident and also proximal epiphysis of tibia with meniscuses are distinquished: 1 — patellar ligament; 2 — subpatellar bursa; 3 — transverse ligament of knee; 4 — articular capsule; 5 — lateral meniscus; 6 — fibular collateral ligament; 7 — posterior cruciformial ligament; 8 — medial meniscus; 9 — fibular collateral ligament; 10 — anterior cruciate ligament.

B — sternoclavicular joint (the right one is opened); 1 — articular disc; 2 — articular capsule; 3 — interclavicular ligament; 4 — anterior sternoclavicular ligament; 5 — costo clavicular ligament; 6 — sternal end of clavicle; 7 — first rib; 8 — sternum.

C — acromioclavicular joint; scapular ligaments: 1 — coracoacromial ligament; 2 — trapezoid ligament; 3 — conoid ligament; 4 — acromial end of clavicle; 5 — coracoid process; 6 — superior transverse scapular ligament; 7 — scapula; 8 — articular lip; 9 — glenoid cavity; 10 — acromion; 11 — acromioclavicular joint and ligament.

made up of two layers: a fibrous membrane on the outside and a synovial membrane inside. The fibrous m e m b r a n e (membrána fibrósa) is thick and very durable. It is formed by fibrous connective tissue. In some places the fibrous membrane is thickened by ligaments, which strengthen the capsule. These l i g a m e n t s are called c a p s u l a r if they are situated within the capsule wall, and e x t r a c a p s u l a r when they are situated outside the capsule. Some joint have i n t r a c a p s u l a r   l i g a m e n t s inside the joint cavity, which are covered by the synovial membrane (e.g. the cruciate ligaments of the knee joint). The thin s y n o v i a l   m e m b r a n e (membrána synoviális) lines the fibrous membrane from the inside, forming microprotrusions called synovial v i l l i, which greatly increase its surface area. Often the synovial membrane forms f o l d s (e.g. in the knee joint), in the base of which there are accumulations of fatty tissue.

The articular cavity (cávum articuláre) is a closed fissure-like space confined by the articular surfaces and capsule. It is filled with synovial fluid, a mucoid lubricant, which moistens the articular surfaces, allowing them to glide freely against each other. Synovial fluid also provides nutrients to the articular cartilage.

Articular discs and menisci (dísci et menísci articuláres) are intraarticular cartilaginous plates of different shapes, which reduce or eliminate incongruity between articular surfaces. Disks, which divide the joint cavity completely into two sections, are found in the sternoclavicular, temporomandibular and some other joints. Menisci form a partial division in the knee joint (Fig.68). Discs and menisci can be shifted during movement, thus acting as shock absorbers.

Some joints (shoulder and hip joints) have an articular labrum, which is attached along the border of the articular surface, increasing the depth of the articular fossa.

CLASSIFICATION OF JOINTS (CONTINUATION)

Joints can be classified based on their anatomy or on their biomechanic properties. According to the anatomic classification, joints are subdivided into simple and compound (composite), depending on the number of bones involved, and into complex and combination joints. Simple joints are formed by two articular surfaces (e.g. the shoulder joint, the hip joint and many other joints). Compound joints (e.g. the radiocarpal joint, etc.) are formed by three or more articular surfaces. Complex joints have an articular disc or meniscus (the sternoclavicular, temporomandibular and knee joints). Combination joints are groups of articulations, which are isolated anatomically, but function simultaneously. An example of this is the temporomandibular joints.

According to the biomechanic classification, joints are subdivided into uniaxial, biaxial and multiaxial, depending on the number of rotation axes they have. Uniaxial joints have one rotation axis, around which they can perform flexion and extension or abduction and adduction movements, or rotation to the outside (supination) and inside (pronation). Uniaxial articulations include hinge (elbow joint) and pivot joints (proximal and distal radioulnar articulations) (Fig.69). Biaxial joints have two axes of rotations, for example, flexion-extension and abduction-adduction. Such joints are the radiocarpal articulation (ellipsoid), the carpometacarpal joint of the thumb and the atlanto-occipital joint (condylar).

Multiaxial (triaxial) joints (shoulder and hip joints) are formed by spherical articular surfaces. They can perform all types of movement: flexion-extension, abduction-adduction and supination-pronation (rotation).
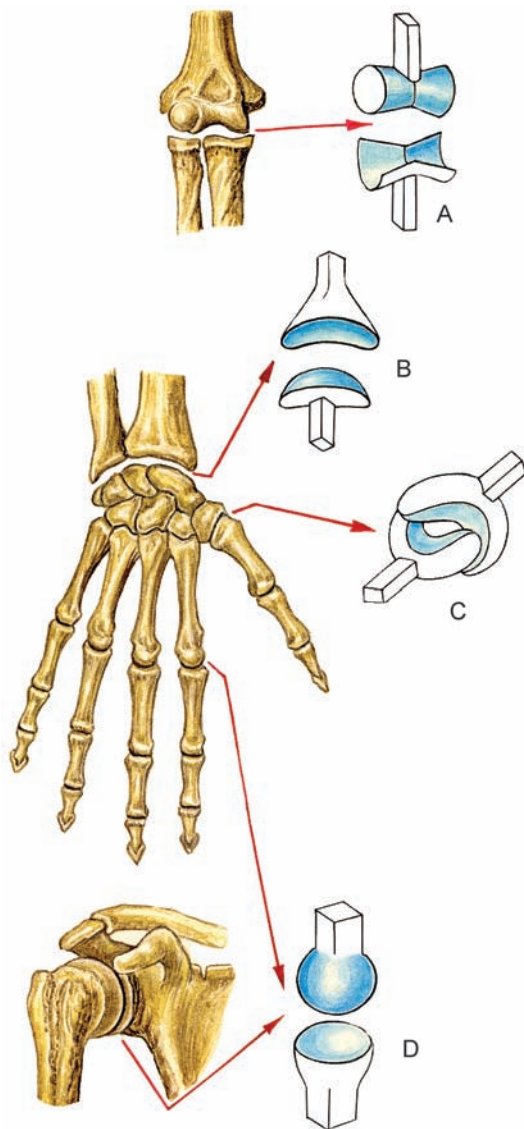
Fig. 69. Articular facets.
A — pivot joint; B — ellipsoid joint; C — saddle joint; D — spheroidal (ball and socket) joint.

Multiaxial joints also include articulations with flat articular surfaces, which resemble spherical surfaces of a large diameter. The articular surfaces of these joints can make only slight gliding movements against each other.

The amplitude of movement in a joint is defined by the shape, size and congruence of articular surfaces. Its mobility also depends on the tension of the articular capsule and its ligaments, as well as on individual, age and sexual characteristics.

Anatomic movement of the joints is defined by the difference in angles of articular surfaces. Thus, if an articular fossa has an angle of 140°, and the articular head — 210°, the possible amplitude of movement will be 70°. The greater is the difference of curvatures of the articular surfaces, the larger is the amplitude of movement in the joint.

AGE CHARACTERISTICS OF JOINTS

In embryogenesis all articulations are at first formed as continuous joints. Later, as bones are gradually drawn closer together, the mesenchyme layer between them becomes thinner and is replaced by fibrous or cartilage tissue. Synovial joints start forming during weeks 6–11 of embryogenesis. A slit appears in the mesenchyme layer between bones and the surrounding mesenchyme forms the articular capsule and ligaments. The deep layer of the capsule transforms into the synovial membrane. In complex articulations such as the knee and temporomandibular joints two articular slits are formed, and the mesenchyme between them transforms into an articular disk or meniscus. The cartilaginous glenoid labrum is formed from articular cartilage, when its central part resolves and becomes thin, while the peripheral part accretes to the borders of the articular surface. Symphyses are formed by transformation of mesenchyme between bones into cartilage, and generation of a narrow slit in its thickness.

In newborns all anatomic parts of joints are formed, however, their differentiation is still taking place. At this age the epiphyses of articulating bones are made up of cartilage. During ages 6–10 the structure of the synovial membrane becomes more complex: the number of synovial villi and folds increases and a vascular network and nerve endings are formed. The capsule goes through collagenation. During this period the capsule and its ligaments become significantly thicker and more durable. The formation of all joint elements becomes completed at age 13–16. With optimal functional loading joints do not undergo any involutional changes for many years. In circumstances of excessive long-term physical loading, as well as during aging, structural and functional changes do take place. These changes include thinning of articular cartilage, sclerosis of the capsule and ligaments, osteophyte formation at the borders of articular surfaces. A typical manifestation of these changes is a decrease of movement in the joint.

Aging of bones and joints can be correlated with constitutional types. In persons with the brachymorphic constitutional type aging in hands, feet and large joints (shoulder joint, elbow joint, etc.) is usually faster compared to people with dolichomorphic constitution. Articular ends of most bones undergo age changes faster in women than in men. Involutional changes of different joints come about in a certain sequence. In terms of timing and intensity of changes, the knee and hip joints, joints of the lumbar section of the vertebral column and the sacroiliac articulation are usually the first to be afflicted. These joints bear significant pressure during standing and walking, which accelerates their deterioration. The next to undergo involution are usually articulations of the cervical section of the spine and upper extremity joints.

Questions for revision and examination

1. What are the different types of joints? Give the description of each type.
2. What are synovial joints?
3. Give the anatomical and biomechanic classifications of joints.
4. What is a syndesmosis? Describe its structure and give an example.
5. What is a synovial bursa? What is its function, and where is it situated?
6. What determines the amplitude of movement in a joint?

ARTICULATIONS OF THE BONES OF THE TRUNK

Joints of the vertebral column

Bodies of adjacent vertebrae are connected by **intervertebral disks (dísci intervertebráales)** or **intervertebral symphyses (sýmphyses intervertebráles)**. Vertebral arches and processes are connected by means of joints and ligaments. Each vertebral disc is composed of a central part called the n u c l e u s p u l p o s u s, and a peripheral part called the a n u - l u s f i b r o s u s. The nucleus pulposus, which is a residue of the notochord (chorda) acts as a shock absorber between bodies of two adjacent vertebrae. Sometimes it contains a narrow horizontal slit, thus making a symphysis (semijoint). The peripheral part of the intervertebral disc (fibrous ring) is formed by fibrous cartilage (Fig. 70, 71).

The thickness of an intervertebral disc depends on its level in the vertebral column and the mobility of the corresponding section of the spine. In the t h o r a c i c p o r t i o n, which is the least mobile, the disks are 3–4 mm thick; in the cervical portion, which has a high degree of movement, disks are 5–6 mm thick, and in the lumbar portion — 10–12 mm.

Articulations between vertebral bodies are supported by the anterior and posterior longitudinal ligaments.

The anterior longitudinal ligament (lig. longitudinále antérius) passes over the anterior surface of vertebral bodies and intervertebral discs. This ligament begins on the pharyngeal tubercle of the occipital bone and the anterior tubercle of the anterior arch of the atlas. It ends at the level of 2–3 transverse lines of the sacrum, accreting firmly with intervertebral discs. The posterior longitudinal ligament (lig. longitudinále postérius) passes over the posterior surfaces of the bodies of vertebrae on the inside of the vertebral canal, be-

Fig. 70. Vertebral joints. Lumbar region; part of vertebral canal is partly opened.

1 — interspinous ligaments; 2 — supraspinous ligament; 3 — ligamentum flava; 4 — posterior longitudinal ligament; 5 — intervertebral disc; 6 — nucleus pulposus; 7 — anterior longitudinal ligament; 8 — costal fossa of XII thoracic vertebra.

ginning at the axial vertebra and down to the level of the first coccygeal vertebra. At the level of the middle atlanto-occipital articulation this ligament connects with the cruciate ligament of atlas, and to the bottom it accretes with the intervertebral discs.

Arches of neighboring adjacent vertebrae are connected by ligamenta flava (ligg. flávae), which are formed by yellowish elastic connective tissue. These ligaments are very durable and resilient.

Between the articular processes there are **zygapophyseal (intervertebral) joints (art. zygapophysiáles s. intervertebráles)**. The articular capsules of these joints are strengthened by fibers, which are attached to the borders of the articular surfaces. These articulations pertain to flat multiaxial immovable joints.
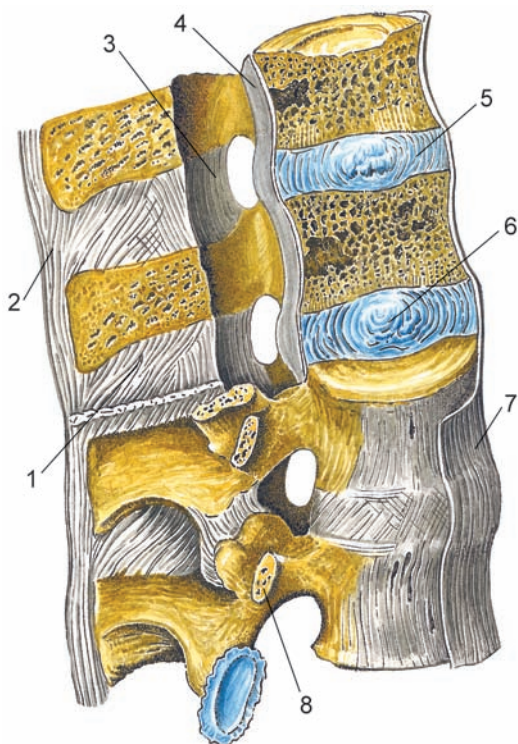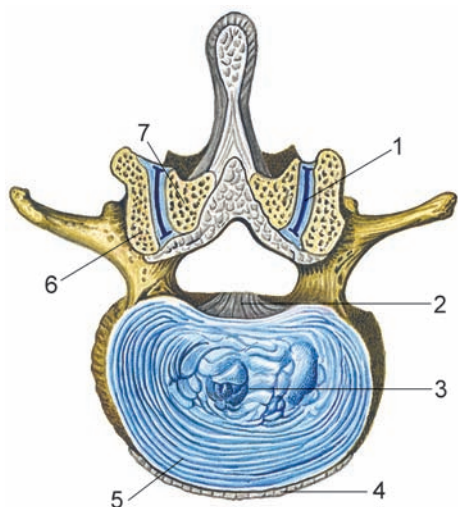
Fig. 71. Intervertebral disc and intervertebral joints.

Horisontal cut between T-XII and L-I vertebrae; superior aspect. 1 — intervertebral joint (opened); 2 — posterior longitudinal ligament; 3 — nucleus pulposus; 4 — anterior longitudinal ligament; 5 — anulus fibrosus; 6 — inferior articular process of XII thoracic vertebra; 7 — superior articular process of I lumbar vertebra.

Vertebral spinous processes are connected with each other by interspinal ligaments (ligg. interspiná-lia) and the supraspinal ligament. The interspinal ligaments are thick fibrous plates situated between the spinous processes. The supraspinal ligament is attached to the apexes of all spinous processes. In the cervical section of the spine, between the external occipital protuberance and the spinal processes of the cervical vertebrae, this ligament is called the nuchal ligament (lig. núchae).

Between transverse processes there are intertransverse ligaments (ligg. intertransversária). These ligaments are frequently absent in the cervical section of the spine.

The sacrococcygeal joint (art. sacrococcýgea) is the articulation between the apex of the sacrum and the first coccygeal vertebra. Its vertebral disc often contains a fissure. Several ligaments strengthen this joint. One of them is the paired lateral sacrococcygeal ligament (lig. sacrococcýgeum laterále), which runs from the lower edge of the lateral sacral crest and is analogous to intertrasversal ligaments. The ventral sacrococcygeal ligament (lig. sacrococcýgeum ventrále) is a continuation of the anterior longitudinal ligament. The superficial dorsal sacrococcygeal ligament (lig. sacrococcýgeum dorsále superficiále) runs between the edge of the sacral hiatus and the posterior surface of the coccyx. The deep dorsal sacrococcygeal ligament (lig. sacrococcýgeum dorsále profúndum) is a continuation of the posterior longitudinal ligament and is situated on the posterior surface of the bodies of the Cx 1 and sacral vertebrae. The sacral and coccygeal horns are joint by connective tissue (syndesmoses). In women the sacrococcygeal joint is more mobile than in men. During labor the coccyx can shift somewhat backwards, which enlarges the maternal pathways.

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Articulations between the vertebral column and skull

The occipital bone of the skull articulates with the C1 and C2 vertebrae. These articulations can be described as highly durable, mobile and complex in structure (table 3).

The atlantooccipital joint (art. atlantooccipitális) is a combination condylar joint. It is formed by the two condyles of the occipital bone and the corresponding superior articular facets of the atlas. Each of these joints has its own articular capsule. They are strengthened by two atlantooccipital membranes. The a n t e r i o r a t l a n t o - o c c i p i t a l m e m b r a n e (membrána atlantooccipitáalis antérior) is stretched between the base of the occipital bone and the anterior arch of the atlas. The p o s t e r i o r a t - l a n t o - o c c i p i t a l m e m b r a n e (membrána atlantooccipitális postérior) is thicker and wider than the anterior membrane. It is attached to the posterior edge of the foramen magnum and the posterior arch of the atlas. The right and left atlantooccipital joints can move simultaneously. They can perform tilting movements (flexion-extention) forward, up to 20°, and backward, up to 30°, about the frontal axis. Movement can also be produced in these joints about the sagittal axis, tilting the head from the median line up to 20°.

The middle atlantoaxial joint (art. atlantoaxiális mediána) is formed by the anterior and posterior articular facets of the dens (Fig. 72). In the front it articulates with the facet for dens on the anterior arch of the
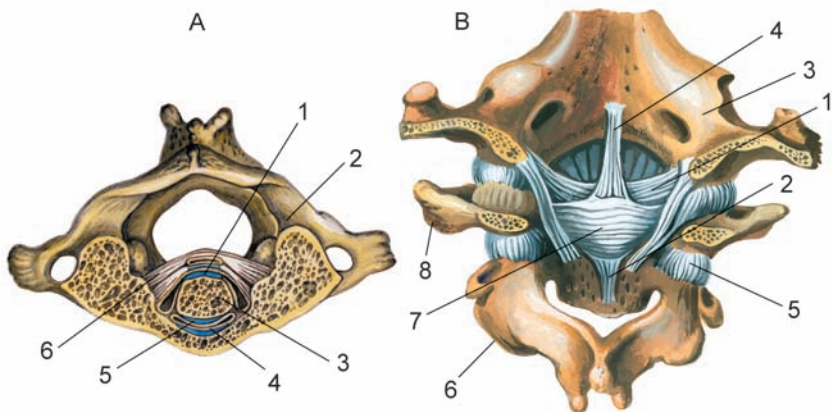
Fig. 72. Atlanto-axial joints.

A — horizontal cut, superior aspect. 1 — posterior articular facet; 2 — superior articular facet; 3 — dens (saw cut); 4 — fovea dentis; 5 — anterior articular facet; 6 — transverse ligament of atlas.

B — ligaments of a median atlantoaxial joint; posterior aspect. Frontal section at a level of posterior arch of atlas. 1 — alar ligament; 2 — longitudinal bands; 3 — occipital bone; 4 — apical ligament of dens; 5 — capsule of atlanto-occipital joint; 6 — axis; 7 — transverse ligament of atlas; 8 — lateral mass.

atlas. In the back it articulates with the transversal ligament. This ligament is stretched between the lateral masses of the atlas. Even though the anterior and posterior articulations of the dens have separate articular cavities and capsules, they are usually considered as a common middle atlantoaxial joint.

By its anatomy and biomechanics the middle atlantoaxial articulation is a uniaxial pivot joint. It performs rotational movements about the vertical axis, turning the skull up to 30–40° to each side.

Table 3. Articulations between the skull and the vertebral column.

Joint	Articular surfaces	Type of joint	Axes of rotation	Movement in joint
Atlantooccipital	Condyle of occipital bone and superior articular surface of atlas	Ellipsoidal; biaxial; combination	Frontal and sagittal	Nodding and bending of the head sideways
Median atlantoaxial joint	Facet for dens and anterior articular surface of dens	Pivot; uniaxial	Vertical	Rotation of the head
Lateral atlantoaxial joint	Inferior articular facet of atlas and superior articular surface of axis	Flat; combination	Multiaxial; slightly movable	Rotation of the head

The lateral atlantoaxial joint (art. atlanto-axiális laterális) is a paired joint. It is formed by articular facets on the atlas with the superior articular facets of the axial vertebra. Each of the the right and left atlantoaxial joints has its own capsule.

The middle atlantoaxial and lateral atlantoaxial joints are strengthened by several ligaments. The apical ligament of the dens (lig. ápicis déntis) is a thin non-paired ligament. It stretches between the anterior edge of the foramen magnum and the apex of the dens. The alar ligaments (ligg. alária) are paired ligaments, each beginning on the lateral surface of the tooth and attached to the inner surface of the occipital condyles. The alar ligaments limit the rotation of the head in the middle atlantoaxial joint.

Behind the ligament of the apex of the dens and the alar ligaments is the cruciate ligament of the atlas (lig. crucifórme atlántis). It is formed by the transverse ligament of the atlas and longitudinal bands of fibrous tissue, which extend upwards and downwards from the ligament. The superior fascicle ends on the anterior edge of the foramen magnum, and the inferior — on the posterior surface of the body of the axial vertebra. Inside the vertebral canal the

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atlatoaxial joints and their ligaments are covered from behind with a wide durable t e c t o r i a l m e m b r a n e (m e m b r á n a t e c t ó r i a). About the level of the axial vertebra this membrane passes into the posterior longitudinal ligament. At the top it ends on the inner surface of the base of the occipital bone. The lateral and middle atlantoaxial joints are combination joints. They perform gliding movements with insignificant shifting of articular surfaces simultaneously with rotation in the middle atlantoaxial joint.

The vertebral column (as a whole)

The vertebral column (colúmna vertebrális), or spine, is formed by vertebrae, which are connected by intervertebral disks (symphyses), ligaments and membranes. The spine provides support and acts as a flexible axis for the torso. It forms part of the posterior wall of the thoracic, abdominal and pelvic cavities and serves as a container for the spinal cord.

In adult women the spine is 60–65 cm long, and in men its length varies from 60 to 75 cm. During old age its length decreases by approximately 5 cm due to increased curvature of the spine and decrease thickness of intervertebral disks. The width of the vertebrae decreases from the bottom upwards. For the T12 it is approximately 5 cm and reaches its greatest values at the base of the sacrum (up to 11–12 cm).

The vertebral column forms several curvatures in the sagittal and frontal planes. A backward curvature is called a kyphosis, forward curvature— a lordosis, and a sideways curve is called a scoliosis. The normal physiological curvatures of the spine are the cervical and lumbar lordoses, the thoracic and sacral kyphoses and the thoracic (aortal) scoliosis. The aortal scoliosis occurs in approximately 1/3 of all cases. It is located at the level of the T3-T5 vertebrae in the form of a slight curve to the right.

Formation of spinal curvatures takes place only after birth, while the spine of a newborn is shaped like a backward curved arc. The cervical lordosis is formed when the infant begins to hold up its head and starts sitting down. Its formation has to do with an increase in tension of the occipital muscles, which upbear the head. The lumbar lordosis forms with the beginning of standing and walking. The thoracic and sacral kyphoses are formed as compensatory simultaneously with the formation of the lordoses.

The c e r v i c a l and l u m b a r l o r d o s e s are usually better expressed in women than in men. Spinal curvatures become somewhat straightened out when the body is in a horizontal position, and are more pronounced when it is situated vertically. They also become more expressed when carrying heavy loads. Incorrect posture (lowered head and chest) results in

an increased thoracic kyphosis and decreased cervical and lumbar lordoses. The t h o r a c i c   k y p h o s i s also becomes notably increased during senescence (humpback appearance). Non-physiological spinal curvatures (scolioses) can form as a result of disease processes or long-term incorrect posture.

Movement of the vertebral column. In spite of insignificant mobility of adjacent vertebrae relative to each other, the spine as a whole has very high mobility. It can perform flexion-extension movements, abduction and adduction, rotation, and circumduction.

Flexion and extention is possible about the frontal axis at total amplitude of 170–245°. During flexion, the bodies of the vertebrae are bent to the front and the spinous processes move away from each other. The anterior longitudinal ligament becomes relaxed. This movement is limited by the tension of the posterior longitudinal ligament, ligamenta flavae, interspinal ligaments and supraspinal ligaments.

During extension of the spine all its ligaments relax, except the anterior longitudinal ligament, which limits the extent of this movement. The configuration of intervertebral disks changes during bending of the spine by a decrease in their height on the side of the inclination and its increase on the opposite side.

Abduction and adduction of the vertebral column is performed relative to the sagittal axis. The total amplitude of this movement is approximately 165°. As the spine inclines to the side, its motion is limited by tension in the ligamenta flavae, intertransverse ligaments and capsules of the zygapophyseal joints.

Rotation of the spine (turning right and left) is performed about the vertical axis with amplitude of about 120°. During rotation the nucleus pulposus acts as the articular head, and the tension in the fibrous rings and the ligamenta flavae limit this movement.

Circumduction of the vertebral column also occurs about its vertical axis. In this case the sacrum acts as a point of support, while the upper end of the spine moves freely in a circular motion.

Articulation of ribs with the vertebral column

The ribs are connected with the vertebrae by **costovértebral jóints (artt. costo-vertevrales)**, each consisting of a joint of the head of the rib and a costotransverse joint.

The joint of the head of the rib (art. cápitis cóstae) is formed by the superior and inferior costal facets (demifacets) of adjacent thoracic verte-

brae and the head of the rib. The articular cavity contains an intra-articular ligament, which extends from the crest of the head of the rib to the intervertebral disk. This ligament is not found on ribs 1, 11 and 12. The capsule of this joint is strengthened on the outside by the r a d i a t e l i g a - m e n t o f t h e h e a d o f t h e r i b (l i g. c á p i t i s c ó s t a e r a d i á t u m). This ligament begins on the anterior surface of the head of the rib and spreads fan-like, attaching to the bodies of adjacent vertebrae and the intervertebral disk.

The costotransverse joint (art. costotransversária) is formed by the tubercle of the rib and the costal facet on the transverse process of a thoracic verebra. The joint has a thin articular capsule, which attaches along the borders of articular surfaces. The capsule is strengthened by the c o s t o t r a n s v e r s e l i g a m e n t (l i g. c o s t o t r a n s v e r s á r i u m). The costotransverse joint and the joint of the head of the rib are combination joints, meaning they move simultaneously. They perform movements about a common axis, drawn though the neck of the rib and the centers of both joints. Rotation of the posterior part of the ribs about this axis transmits movement onto the anterior part of the ribs that are connected with the sternum.

Articulation of the ribs with the sternum

The ribs are connected with the sternum by synovial and cartilage joints (table 4). The cartilage of rib 1 fuses with the sternum forming a synchondrosis. Cartilages of ribs 2–7 articulate with the sternum by **sternocostal joints (artt. sternocostáles)**. In these joints the anterior ends of costal cartilages and the costal notches of the sternum serve as articular surfaces. The articular capsules are continuations of the perichondrium of costal cartilages, which pass into the periosteum of the sternum. The capsules are strengthened by the r a d i a t e s t e r n o c o s t a l l i g a m e n t s. In the front these ligaments accrete with the periosteum of the sternum, forming a thick s t e r n a l m e m b r a n e (membrána stérni). The joint of rib 2 has an i n t r a - a r t i c u l a r s t e r n o c o s t a l l i g a m e n t.

The costal cartilages of ribs 7–10 are joint with the cartilage of the corresponding overlying rib. These articulations are sometimes in the form of interchondral joints.

The anterior sections of the ribs are connected by the e x t e r n a l i n - t e r c o s t a l m e m b r a n e (m e m b r á n a i n t e r c o s t á l i s e x t é r n a). Its fibers are directed forward from top to bottom. The posterior sections of the ribs are connected by the i n t e r n a l i n t e r c o s t a l m e m b r a n e (m e m b r á n a i n t e r c o s t á l i s i n t é r n a). The fibers of this membrane are oriented backwards from the bottom to the top.

Table 4. Joints of the vertebral column and sternum.

Joints	Articular surfaces	Type of joint	Axes of rotation	Movement in joint
Joints of the heads of ribs	Articular facets on heads of ribs and costal facets (demifacets) on thoracic vertebrae	Spherical; combination	Multiaxial	Raising and lowering of ribs
Costotrans-verse joints	Articular facets on tubercles of ribs and costal facets on transverse processes	Flat; combination	Multiaxial	Lifting and lowering of ribs
Sternocostal joints	Sternal ends of costal cartilages and costal notches	Flat	Multiaxial; slightly movable	Raising and lowering of ribs
Interchondral joints	Cartilages of ribs 8-10 connect with each other and cartilages of rib 8 connects to the seventh costal cartilage	Flat	Multiaxial; slightly movable	Raising and lowering of ribs; movement is limited

The thorax (as a whole)

The thorax (compáges thóracis) consists of 12 thoracic vertebrae, 12 pairs of ribs and the sternum. The thoracic cavity serves as a container for the heart, large blood vessels, the esophagus and other organs.

The thorax is flattened in the anteroposterior direction; it has the shape of an incorrect cone. It has four walls (anterior, posterior and two lateral) and two apertures (superior and inferior).

The anterior wall is formed by the sternum and costal cartilages; the posterior wall — by the thoracic vertebrae and the posterior sections of ribs; the lateral walls are formed by their side sections. The ribs are separated by i n t e r c o s t a l s p a c e s (s p á t i u m i n t e r c o s t á l e s). The s u p e r i o r a p e r t u r e of the thorax (apertura thoracis superior) is limited by the T1 vertebra, the inner edges of the first pair of ribs and by the superior edge of the manubrium sterni. Its measures 5–6 cm from front to back and 10–12 cm across.

The i n f e r i o r a p e r t u r e of the thorax is limited by the body of the T12 vertebra in the back, the xiphoid process of the sternum in the front, and by the lowest ribs at the sides. Its anteroposterior size in the middle is 13–15 cm and the greatest transversal length is 25–28 cm. The anterolater-

al border of this inferior aperture, which is formed by the joints between ribs 7–10, is called the costal arch (arcus costalis). The right and left costal arches limit the i n f r a s t e r n a l   a n g l e (á n g u l u s   i n f r a s t e r n á l i s). At the apex of this angle is the xiphoid process.

The shape of the thorax depends upon many factors, in particular, the constitutional type. People of brachymorphic constitution have a cone-shaped thorax. Its superior portion is notably narrower than the inferior part, while the infrasternal angle is obtuse. The ribs are slightly inclined forward, the difference between the transversal and anteroposterior dimensions is small. In people with dolichomorphic constitution the thorax has a flattened form. Its anteroposterior size is significantly less than the transversal, the ribs are heavily inclined downward and to the front, while the infrasternal angle is acute. In the mesomorphic constitutional type the thorax is typically cylindrical. Its shape is intermediate between conical and flattened. In women the thorax is shorter and more spherical compared to men. In a newborn its anteroposterior size is greater than the transverse one. During senescence the thorax becomes longer and more flattened due to the age decrease in muscle tension and the lowering of the anterior sections of the ribs.

The shape of the thorax may be affected by some diseases. For example, rachitis causes the anteroposterior measurement of the thorax to increase, notably projecting the sternum forward («pigeon-breast»).

Movements of the thorax. Movements of the thorax are connected with the acts of inspiration and expiration. During inspiration the ribs and sternum rise, and the intercostal spaces widen, increasing the volume of the thoracic cavity. During expiration the ribs and the sternum move down, the intercostal spaces become narrower and the dimensions of the thorax decrease.

Lowering of the ribs occurs not only due to the work of appropriate muscles but also owing to the weight of the thorax and elasticity of the costal cartilages.

Questions for revision and examination

1. Name the articulations found between vertebrae. How are they constructed in different parts of the vertebral column?

2. Describe the connection between the skull and the spine.

3. Name the curvatures of the spine. At what ages do they appear and what causes them to develop?

4. What is the structure of joints between the ribs and the vertebrae? What kind of movements are these joints capable of?

5. Describe the possible shapes and dimensions of the thorax.

ARTICULATIONS OF THE BONES OF THE SKULL

The bones of the skull are connected mainly with continuous articulations called sutures. The exception is the temporomandibular joint (table 5).

Sutures are usually named according to the bones, which they connect. The medial margins of the parietal bones are connected by the serrate s a g i t t a l s u t u r e (s u t ú r a s a g i t t á l i s). The suture between the frontal and parietal bones is called the c o r o n a l s u t u r e (s u t u r a c o r o n á l i s); between the temporal and occipital bones is the serrate l a m b d o i d s u t u r e (s u t ú r a l a m b d o í d e a). The temporal squama is connected with the major wing of sphenoidal bone and the parietal bone by a s q u a m o u s s u t u r e (s u t ú r a s q u a m ó s a), while bones of the visceral cranium are connected by plane, or harmonic, sutures. Sometimes there are inconstant sutures, formed by non-fusion of separate points of
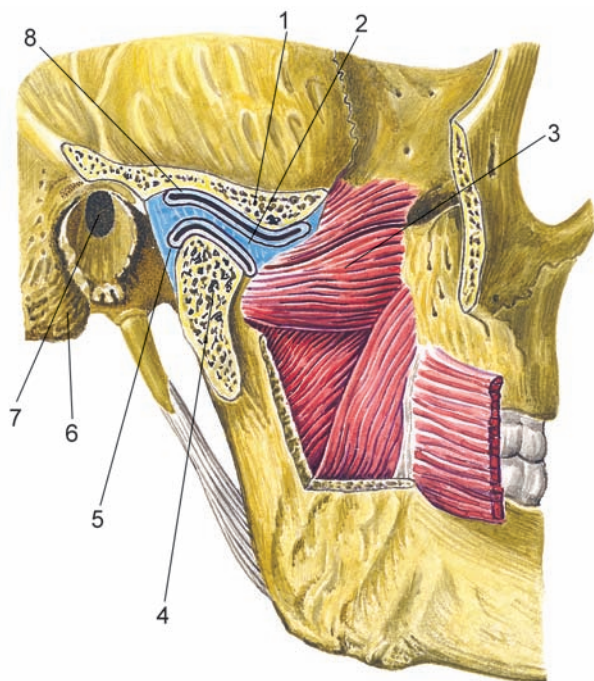

Fig. 73. Temporomandibular joint. Sagittal section. Right aspect.

1 — mandibular fossa; 2 — articular disc; 3 — lateral pterygoid muscle; 4 — head of mandible; 5 — articular capsule; 6 — mastoid process; 7 — external acoustic opening; 8 — articular cavity.

ossification (an example of this is the median, or metopic, suture of the frontal bone).

In the area of the cranial base there are cartilaginous articulations, or synchondroses. Between the body of sphenoid bone and the base of the occipital bone is the s p h e n o - o c c i p i t a l   s y n c h o n d r o s i s (s y n-c h o n d r ó s i s   s p h e n o - o c c i p i t á l i s). Between the pyramid of the temporal bone and the base of the occipital bone is the p e t r o - o c c i p i-t a l   s y n c h o n d r o s i s (synchondrósis petro-occipitális). At certain ages most synchondroses become replaced by bone tissue.

The temporomandibular joint (art. temporomandibuláris) is formed by the head of the maxilla, the mandibular fossa and the articular tubercle of the temporal bone (Fig. 73), all covered by fibrous cartilage. The joint has a loose articular capsule, which attaches in front of the articular tubercle and near the petrotympanic fissure of the temporal bone. The articular capsule is fused with the peripheral parts of t h e   i n t r a - a r t i c-u l a r   d i s c. This disc divides the articular cavity into two isolated compartments (stories).

Table 5. Articulations found in the skull.

Continuous joints		
Region of the skull	Type of joints	Variation of joint
Roof of the skull	Syndesmoses	Serrate sutures, including coronal, lambdoide, sagittal and squamous
Facial skull	Syndesmoses	Plane (flat, harmonious) sutures
Joints between teeth and dental alveoli	Syndesmoses	Gomphoses
Base of the skull	Temporary synchondroses, which become replaced by synostoses (including sphenooccipital, sphenopetrosal, petrooccipital, interoccipital and sphenoethmoidal)	

Discontinuous joint				
Joint	Articular surfaces	Type of joint	Axes of rotation	Movement in joint
Temporomandibular joint	Mandibular fossa of temporal bone and head of mandible (the joint contains an articular disc)	Ellipsoidal; biaxial; combination	Frontal and vertical	Depression and elevation of mandible; its protraction and retraction

The mandibular joint is strengthened by several ligaments. The l a t - e r a l l i g a m e n t forms a lateral thickening of the capsule. There are two ligaments on the outside of the joint: the s p h e n o m a n d i b u l a r l i g a - m e n t begins on the spine of the sphenoid bone and attaches to the mandibular lingula. The s t y l o m a n d i b u l a r l i g a m e n t begins on the styloid process of the temporal bone and attaches on the internal surface of the mandible, near its angle.

The temporomandibular joint is paired. It is a complex (has a joint disk), combination ellipsoid joint. The right and left temporomandibular joints are capable of movements in which the mandible is elevated and depressed (opening and closing of the mouth); protracting the mandible forward and retracting it back; moving the mandible to the right and left (lateral movements).

Questions for revision and examination

1. Name the sutures between bones of the skull. By what characteristics can these sutures differ from each other?
2. What synchondroses are found in the base of the skull?
3. Describe the structural characteristics of the temporomandibular joint.
4. What movements are possible in the temporomandibular joint?

ARTICULATIONS OF THE UPPER EXTREMITIES

Articulations of the pectoral girdle

Joints of the pectoral girdle connect the clavicle with the scapula and the sternum.

The sternoclavicular joint (art. sternoclaviculáris) is formed between the sternal end of the clavicle and the clavicular notch of the sternum. The shape of its articular surfaces is close to saddle-like. The joint contains an a r t i c u l a r d i s c, which accretes with its periphery to the joint capsule. The joint capsule is strengthened by the a n t e r i o r and p o s - t e r i o r s t e r n o c l a v i c u l a r l i g a m e n t s. An i n t e r c l a v i c u l a r l i g a m e n t passes over both sternoclavicular joints and the jugular notch of the sternum (between sternal ends of the clavicles). Each joint is also strengthened by the extracapsular c o s t o c l a v i c u l a r l i g a m e n t, which connects the bottom surface of the sternal end of the clavicle and the upper surface of the 1st rib.

The movements possible in the sternoclavicular joint are elevation and depression of the clavicle up and down about the sagittal axis; protraction and retraction of the acromial end forward and back about the vertical axis, and circumduction. The amplitude of movements is limited.

The **acromioclavicular joint (art. acromioclaviculáris)** is formed by the acromial end of the clavicle and the articular surface of the acromial process. In 30 percent of cases the joint contains an articular disc. The capsule is attached on the edges of the articular surfaces. On the top it is strengthened by the acromioclavicular ligament. Separate from the joint there is a strong c o r a c o c l a v i c u l a r   l i g a m e n t, which consists of two parts. The first part is attached to the trapezoid line of the clavicle and is called the trapezoid ligament. The second part is attached to t h e c o n o i d   t u b e r c l e (the   c o n o i d   l i g a m e n t).

Movements in the acromioclavicular joint are possible about three axes. The amplitude of these movements, however, is insignificant, because they are significantly limited by ligament.

Proper ligaments of the scapula. Between the separate parts of the scapula there are ligaments, which do not directly contribute to the acromioclavicular and sternoclavicular joints.

One of these ligaments is the c o r a c o - a c r o m i a l   l i g a m e n t (lig. coraco-acromiále) which is a strong fibrous plate stretched between the apex of the acromion and the coracoid process. The s u p e r i o r   t r a n s - v e r s e   s c a p u l a r   l i g a m e n t connects edges of the scapular notch, transforming it into an aperture.

The i n f e r i o r   t r a n s v e r s e   s c a p u l a r   l i g a m e n t is situated on the posterior surface of the scapular notch, connecting the base of the acromion and the posterior margin of the scapular articular fossa.

Articulations of the free upper extremity

Articulations of the free upper extremity include joints between the scapula, the humerus, bones of the forearm and hand.

The glenohumeral (shoulder) joint (art. húmeri) is formed by the glenoid cavity of the scapula and the head of the humerus (Fig. 74).

The articular surface of the head is spherical and exceeds the size of the flat surface of the glenoid cavity almost by three times. The glenoid fossa is supplemented around the margins by a f e n o i d   l a b r u m (l á b r u m g l e n o i d á l e), which increases the congruence of articular surfaces and the depth of the articular cavity. The articular capsule is attached to the external surface of the glenoid labrum and to the anatomical neck of the humerus. The capsule of the shoulder joint is thin and loose. At the top it is strengthened by the c o r a c o h u m e r a l   l i g a m e n t, which begins on the base of the coracoid process and attaches to the upper part of the anatomical neck of the humerus. The capsule is also penetrated by fibers of muscles tendons (of the supraspinatus muscle, etc). The synovial membrane of this joint forms two protrusions. One is the intertubercular synovial sheath,
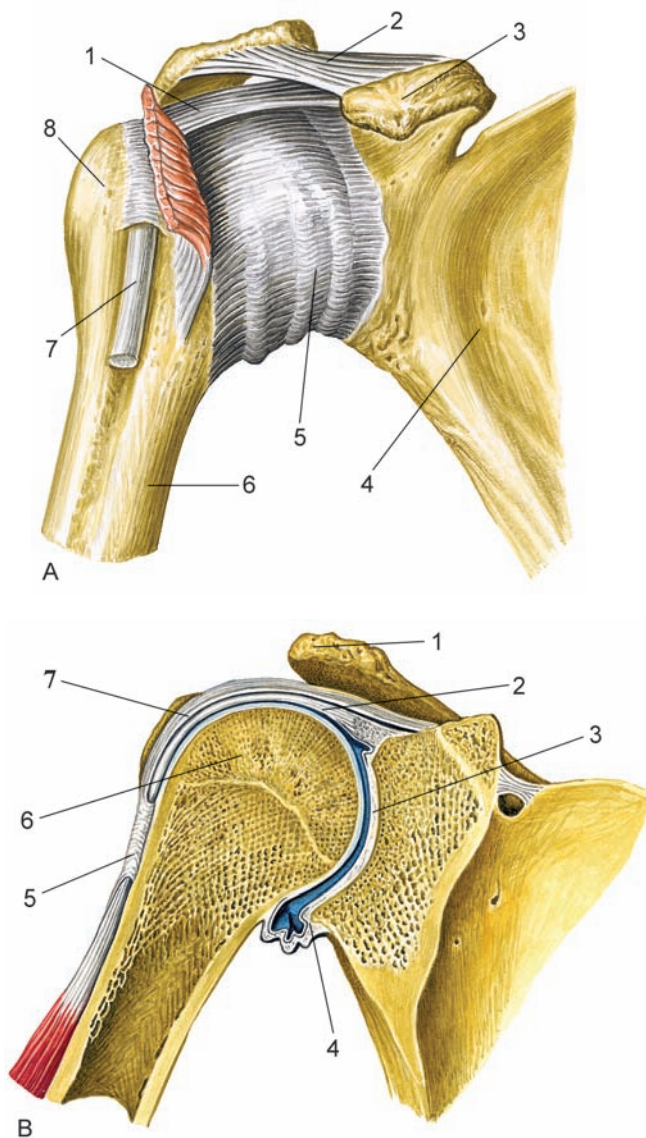
Fig. 74. Shoulder joint.

A — anterior aspect. 1 — coracohumeral ligament; 2 — coracoacromial ligament; 3 — coracoid process; 4 — scapula; 5 — articular capsule; 6 — humerus; 7 — tendo of biceps brachii; 8 — greater tubercle of humerus.

B — frontal section: 1 — coracoid process; 2 — tendo of long caput of m. biceps brachii; 3 — glenoid cavity; 4 — articular capsule; 5 — intertubercular tendon sheath; 6 — head of humerus; 7 — subdeltoid bursa.

which encases the tendon of the long head of the biceps muscle, which passes through the articular cavity. The second protrusion is a subtendineal bursa, found at the base of the coracoid process, beneath the tendon of the subscapular muscle.

The shoulder joint is a typical spheroid (ball-and-socket) joint with large amplitude of movement, which is allowed by the loose articular capsule, a large difference in size of articular surfaces and an absence of thick ligaments. It can perform flexion and extension movements about the frontal axis. The total amplitude of these movements is 120°. Abduction and adduction are performed about the sagittal axis with total amplitude of 100°. Supination and pronation are performed about the vertical axis with a total volume of movement of 135°. The shoulder joint can also carry out circumduction. The upper extremity can be raised above the horizontal level only with additional movement in the sternoclavicular joint, because the coracoacromial ligament limits this motion in the shoulder joint.

The elbow joint (art. cúbiti) is formed by the humerus, the radius and the ulna (it is a compound joint). These bones actually form three joints, which are enclosed in a common articular capsule (Fig. 75).

The h u m e r o u l n a r   j o i n t is a hinge joint, formed between the trochlea of the humerus and the trochlear notch of the ulna. The h u m e r - o r a d i a l   j o i n t is spherical, and is formed between the capitulum of the humerus and the head of the radius. The p r o x i m a l   r a d i o u l n a r   j o i n t (a r t.   r a d i o u l n á r i s   p r o x i m á l i s) is cylindrical and is formed by the articular surface on the head of radius and the radial notch of the ulna. The common articular capsule is loose. Proximally it attaches above the articular cartilage of the trochlea of the humerus, thus placing the coronoid and olecranon fossae on the inside of the articular cavity. The lateral and medial epicondyles of the humerus are located outside the articular cavity. On the ulna the articular capsule is attached below the articular cartilage of the coronoid process and along the margin of the trochlear notch. On the radius the capsule is attached at its neck. The articular capsule is strengthened by three ligaments. The u l n a r   c o l l a t e r a l   l i g a - m e n t (l i g.   c o l l a t e r á l e   u l n á r e) begins on the medial epicondyle of humerus and attaches to the medial margin of the trochlear notch of ulna. The r a d i a l   c o l l a t e r a l   l i g a m e n t (l i g.   c o l l a t e r á l e   r a d i á l e) begins on the lateral epicondyle of the humerus and then divides into two fascicles. The anterior fascicle passes over the neck of the radius and attaches near the external anterior edge of the trochlear notch. The posterior fascicle circles the neck of the radius from behind and entwines into the annular ligament of the radius. The a n u l a r   l i g a m e n t   o f   r a d i u s (l i g.   a n u l á r e   r á d i i) begins on the anterior edge of the
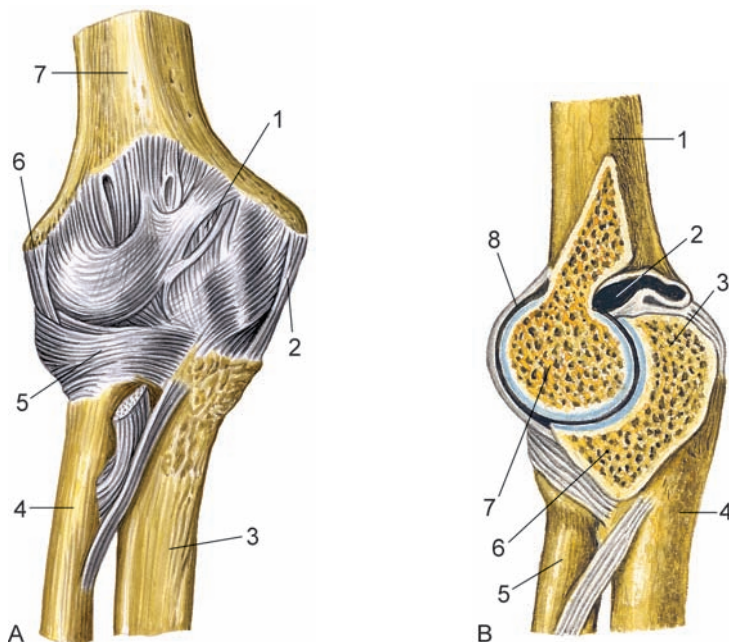
Fig. 75. Elbow joint.

A — Anterior aspect. 1 — articular capsule; 2 — ulnar collateral ligament; 3 — ulna; 4-radius; 5 — anular ligament of radius; 6 — radial collateral ligament; 7 — humerus.

B — Sagittal section: 1 — humerus; 2 — articular cavity; 3 — olecranon; 4 — ulna; 5 — radius; 6 — coronoid process; 7 — trochlea of humerus; 8 — articular capsule.

radial notch of ulna, circles the neck of the radius and attaches to the posterior edge of the radial notch.

The elbow joint performs flexion and extension of the forearm at total amplitude of 170°. During flexion the forearm deviates slightly medially, so that the hand is brought to the chest and not the shoulder. This takes place because the block of the humerus has a small furrow, which directs the displacement of the forearm and hand in a spiral fashion. The proximal radioulnar joint is used for rotation of the radius together with the hand about its longitudinal axis. This movement takes place simultaneously with movement in the distal radioulnar joint.

Articulations of the forearm and hand

Bones of the forearm are connected with continuous and discontinuous articulations. The discontinuous junction is the i n t e r o s s e o u s m e m - b r a n e o f t h e f o r e a r m (membrána interóssea ante-

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b r á c h i i), which is a strong connective tissue membrane, stretched between the interosseous margins of the radius and ulna.. Below the proximal radio-ulnar joint there is a fibrous cord stretching between the two bones called the o b l i q u e   c h o r d a (c h ó r d a   o b l í q u a).

Continuous junctions include the distal radioulnar joint, the radiocarpal (wrist) joint and joints of the hand.

The distal radioulnar joint (art. radioulnaris distalis) is formed between the head of the ulna and the ulnar notch of the radius. This joint is separated from the radiocarpal joint by an articular disc, stretched between the ulnar notch of radius and the styloid process of ulna. The joint capsule of the distal radio-ulnar joint is loose; it attaches along the edges of articular surfaces and the joint disc. The capsule usually protrudes proximally between the ulna and radius, forming a s a c c i f o r m   r e c e s s.

The proximal and distal radioulnar joints together form a combination cylindrical joint. It performs rotation of the radius together with the hand around the ulna. During this movement the proximal epiphysis of the radius describes an arch about the head of ulna. The average amplitude of rotation in the radioulnar joints (supination and pronation together) is approximately 140°.

The radiocarpal (wrist) joint (art. radiocárpea) is the connection between the forearm and the hand. The joint is formed by the carpal articular surface of the radius, the articular disc (on the medial side), and the proximal row of the carpus (the lunate, triquetral and scaphoid bones). The thin articular capsule attaches along the edges of the articulating surfaces and is strengthened by several ligaments (Fig. 76).

The r a d i a l   c o l l a t e r a l   l i g a m e n t   o f   t h e   w r i s t (lig. c o l l a t e r á l e   r a d i á l e) begins on the styloid process of the radius and extends to the scaphoid bone. The u l n a r   c o l l a t e r a l   l i g a m e n t (lig. c o l l a t e r á l e   u l n á r e) passes from the styloid process of the ulna to the triquetral and pisiform bones of the wrist. The p a l m a r   r a d i o c a r p a l   l i g a m e n t (lig.   r a d i o c á r p e u m   p a l m á r e) connects the anterior margin of the articular surface of the radius with the bones of the proximal row of the carpus and with the capitate bone. The d o r s a l   r a d i o c a r p a l   l i g a m e n t (lig.   r a d i o c á r p e u m   d o r s á l e) extends from the posterior margin of the articular surface of the radius to the proximal row of the carpus.

In structure the radiocarpal joint is compound ellipsoid, with movement possible about two axes (frontal and sagittal).

Bones of the hand are linked together by numerous joints with differently shaped articular surfaces, which, combined, allow the hand significant mobility.
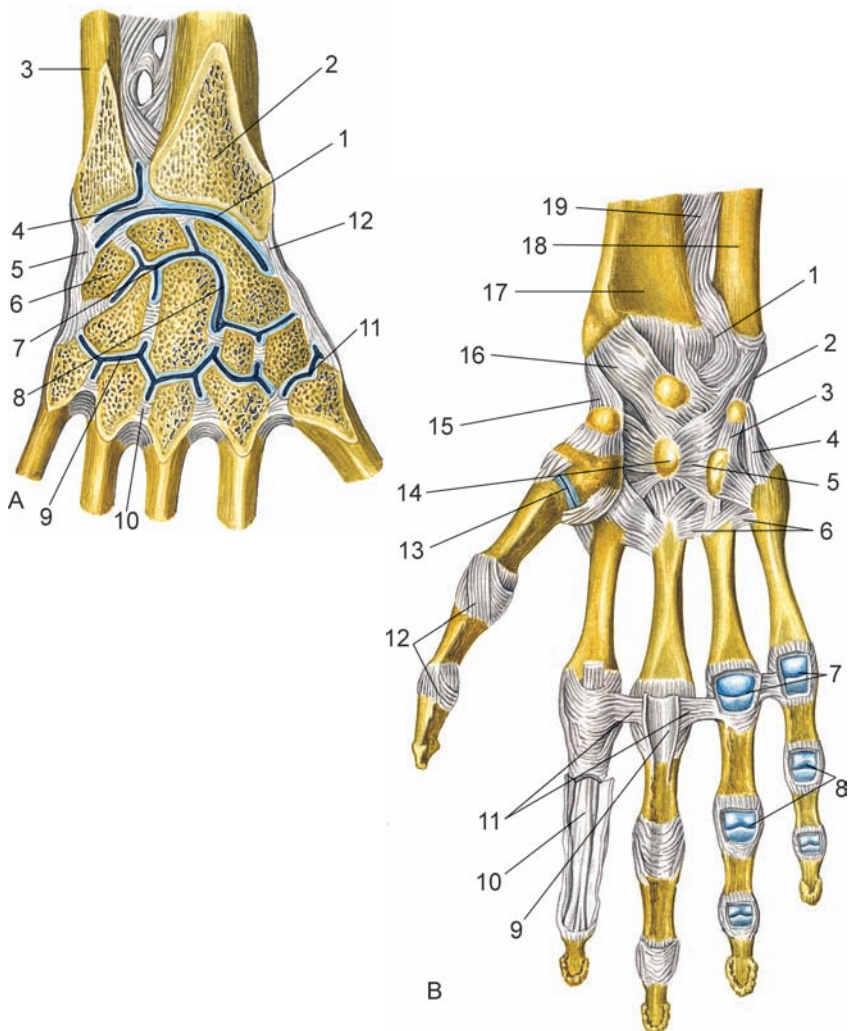
Fig. 76. Joints and ligaments of hand.

A — frontal cut of left wrist joint and joints of carpal bones; anterior aspect. 1 — wrist joint; 2 — radius; 3 — ulna; 4 — articular disc; 5 — ulnar collateral ligament; 6 — pisiform; 7 — midcarpal joint; 8 — intercarpal joints; 9 — carpometocarpal joint; 10 — interosseous metacarpal ligaments; 11 — carpometacarpal joint of thumb; 12 — radial collateral ligament.

B — anterior aspect: 1 — distal radioulnar joint; 2 — ulnar collateral ligament of wrist; 3 — pisohamate ligament; 4 — pisometacarpal ligement; 5 — radial collateral ligament of wrist joint; 6 — palmar metacarpal ligaments; 7 — metacarpophalangeal joints; 8 — interphalangeal joints (opened); 9 — fibrous sheath of digit of hand (opened); 10 — tendo m. flexor digitorum profundus; 11 — deep transverse metacarpal ligaments; 12 — collateral ligaments; 13 — carpometacarpal joint of thumb; 14 — hamate; 15 — radial collateral ligament of wrist joint; 16 — palmar radiocarpal ligament; 17 — radius; 18 — ulna; 19 — interosseus membrane of forearm.

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The **midcarpal joint (art. mediocárpea)** is formed by articulating surfaces of the first and second rows of carpal bones. It is a compound hinge joint. The articular capsule is thin, especially on the dorsal side. It attaches along the edges of the articular surfaces. The midcarpal and radiocarpal joints are functionally connected.

The **intercarpal joints (artt. intercárpeae)** are formed between neighboring bones of the wrist. Their capsules attach on the edges of the articular surfaces. The articular cavities of the intercarpal joints communicate with the cavity of the midcarpal joint.

The midcarpal and intercarpal joints are strengthened by many ligaments. On the palmar surface this is the r a d i a t e c a r p a l l i g a m e n t (lig. c á r p i r a d i á t u m), which is formed by fibrous fascicles spread in a fan-like fashion from the capitate bone to neighboring bones. Adjacent bones of the carpus are connected by the p a l m a r and d o r s a l i n t e r c a r p a l l i g a m e n t s. Some bones are connected by intra-articular ligaments.

The intercarpal joints also include the p i s i f o r m j o i n t (art. óssis pisifórmis), which is strengthened by the p i s o m e t a c a r p a l and p i s o h a m a t e l i g a m e n t s, which are a continuation of the tendon of the ulnar flexor muscle.

The **carpometacarpal joints (artt. carpometacarpáles)** are formed between articular surfaces on the second row of carpal bones and the bases of metacarpal bones. These are plane (gliding) joints (for the II–V metacarpals) with a common articular fissure (cavity). The articular capsule is taut and thin; it attaches along the margins of articular surfaces. The articular cavity is communicated with articular cavities of the midcarpal and intercarpal joints. The capsule is strengthened by the d o r s a l and palmar carpometacarpalia ligaments (ligg. c a r p o m e t e c a r p á l i a d o r s á l i a e t p a l m á r i a).

The c a r p o m e t a c a r p a l j o i n t o f t h e t h u m b is a saddle joint formed between the articular surface of the trapezium and the base of the I metacarpal bone. The joint has high mobility (see below).

The **intermetacarpal joints (artt. intercarpeae)** are formed between adjoining sides of bases of II–V metacarpal bones. Their joint capsule is a continuation of the capsule of the carpometacarpal joints, and is strengthened by the transverse d o r s a l a n d p a l m a r m e t a c a r p a l l i g a m e n t s (ligg. m e t a c a r p á l i a d o r s á l i a e t p a l m á r i a) and also the i n t e r o s s e o u s m e t a c a r p a l l i g a m e n t s (ligg. m e t a c a r p á l i a i n t e r ó s s e a). The latter are intra-articular ligaments, which connect adjacent surfaces of the metacarpal bones.

The metacarpophalangeal joints (artt. metacarpophalangeae) are formed between the bases of proximal finger phalanges and heads of metacarpal bones. The loose joint capsules are attached along the edges of articular surfaces and are strengthened ligaments. On the palmar surface the capsule is thickened by the p a l m a r l i g a m e n t s, and on each side by the c o l l a t e r a l l i g a m e n t s. Between the heads of the II–V metacarpal bones are the deep transverse metacarpal ligaments (ligg. metacarpeae transvera profunda).

The interphalangeal joints (art. interphalangea) are formed between the heads and bases of adjacent phalanges. In structure these are hinge joints. Their articular capsules are loose, attached along the edges of articular cartilages. The capsules are strengthened in front and on the sides by the p a l m a r and c o l l a t e r a l l i g a m e n t s, respectively.

Movement in joints of the hand

Displacement of the hand relative to the forearm is conducted by simultaneous movement in a group of joints, which, for convenience, in clinical practice are called the hand joint.

Characteristics of the joints of the upper extremities are demonstrated in the 6 table.

The carpal joint is ellipsoid, allowing for movements about the frontal and the sagittal axes. Flexion and extension are carried out about the frontal axis with amplitude of 100°, while abduction and adduction are performed about the sagittal axis with the volume of 70°. Circumduction in the carpal joint is conducted through successive movements about the frontal and sagittal axes.

The carpometacarpal joint of thumb is used for opposition and reposition of the thumb relative to the other fingers (about the frontal axis), as well as abduction and adduction of the thumb relative to the index finger (about the sagittal axis). Circumduction in this joint is a result of a succession of movements about the frontal and sagittal axes.

The carpometacarpal joints (II–V) are only slightly movable. The carpometacarpal and intercarpal joints are capable of only insignificant gliding movements. Flexion and extension movements are executed around the frontal axis with a total volume of 90°. Abduction and adduction are conducted about the sagittal axis within limited amplitude. Metacarpophalangeal joints are also capable of circumduction. Movements in the interphalangeal joints are possible about the frontal axis (flexion and extention) with a total volume of approximately 90°.

Table 6. Joints of the upper extremities.

Joint	Articular surfaces	Type of joint	Axes of rotation	Movement in joint
Sternoclavicular joint	Sternal articular surface of clavicle and clavicular notch (contains an articular disc)	Plane; complex	Multiaxial	Raising and lowering of the clavicle, movement forward and backward, and circumduction
Acromioclavicular joint	Articular facet of acromion and acromial articular surface of clavicle	Plane	Multiaxial	Raising and lowering of the clavicle, movement forward and backward, and rotation of clavicle
Shoulder joint	Head of humerus and glenoid cavity (contains a glenoid labrum)	Spherical (ball and socket)	Multiaxial	Flexion and extension, abduction and adduction, supination and pronation and circumduction
Elbow joint:	Trochlea of humerus and trochlear notch of ulna	Trochlear (hinge)	Uniaxial	Flexion and extension of forearm
Humero-ulnar joint	Capitulum of trochlea and articular surface of head of radius	Spherical	Multiaxial	Rotation of radius; flexion and extension of forearm
Humero-radial joint	Articular circumference of radius and radial notch of ulna	Cylindrical (pivot)	Uniaxial	Rotation of radius (pronation and supination)
Proximal radioulnar joint	Articular circumference of ulna and ulnar notch of radius	Cylindrical (pivot)	Uniaxial	Rotation of radius (pronation and supination)
Distal radioulnar joint	Articular surface of radial bone and proximal surfaces of the first row of carpal bones: scaphoid, lunate and triquetrum	Ellipsoidal; compound; complex	Biaxial (sagittal and frontal axes)	Abduction and adduction, and flexion and extension

Radiocarpal joint	Adjacent articular surfaces of the first and second rows of carpal bones (except pisiform)	Plane	Uniaxial	Flexion and extension of hand
Midcarpal joint	Articular surfaces of the second row of carpal bones and bases of II-V metacarpal bones	Saddle joint	Multiaxial	Limited movement
Carpometacarpal joints	Articular surface of trapezium and base of first metacarpal bone	Flat	Biaxial (frontal and sagittal axes)	Flexion and extension, and abduction and adduction of thumb
Carpometacarpal joint of thumb	Adjoining articular facets of metacarpal bones	Ellipsoidal	Multiaxial	Limited movement
Intermetacarpal joints Metacarpophalangeal joints	Articular facets of metacarpal bones and bases of phalanges	Ellipsoidal	Biaxial	Flexion and extension, abduction and adduction of fingers
Interphalangeal joint	Adjoining heads and bases of phalanges		Biaxial	Flexion and extension of phalanges phalanges

1. Which bones do the clavicle and the scapula articulate with? Name the joints formed between these bones.
2. Describe the structural characteristics of the shoulder joint and how they effect various movements.
3. The formation of which joints do the ulna and radius participate in?
4. Describe the structure of the radiocarpal joint. What ligaments strengthen it?
5. What structural characteristics allow for opposition and reposition of the thumb relative to the other fingers?

ARTICULATIONS OF THE LOWER EXTREMITIES

Articulations of the pelvic girdle

Articulations of the pelvic girdle include the paired sacroiliac joint and the pubic symphysis (Fig. 77).

The sacroiliac joint (art. sacroiliáca) is formed between the auricular surfaces of the sacrum and the pelvis. Its articular capsule is very thick and taut; it attaches around the edges of the articular surfaces, accreting with the periosteum of the pelvis and sacrum. The capsule is strengthened by several thick durable ligaments. The a n t e r i o r s a c r o i l i a c l i g a m e n t stretch between the front edges of the articulating surfaces. The posterior part of the capsule is supported by the p o s t e r i o r s a c r o i l i a c l i g a m e n t. The most durable are the i n t e r o s s e o u s s a c r o i l i a c l i g a m e n t, stretched on the posterior surface of the joint between the articulating bones. Also there is the i l i o l u m b a r l i g a m e n t, which connects transverse processes of L4 and L5 vertebrae with the iliac tuberosity. In shape of articulating surfaces this is a plane joint. Movement in it, however, is almost impossible, due to the undulation of articulating surfaces and the taut articular capsule and ligaments.

The pubic symphysis (sýmphysis púbica) is a fibrocartilaginous i n t e r p u b i c d i s c (d í s c u s i n t e r p ú b i c u s), situated between the symphysis surfaces of the pubic bones. This disk has a narrow fissure-like cavity. The pubic symphysis is strengthened by several ligaments. The s u p e r i o r p u b i c l i g a m e n t (l i g. p ú b i c u m s u p é r i o r) stretches transversely upward from the symphysis, connecting the two pubic bones. The i n f e r i o r p u b i c l i g a m e n t (l i g. p ú b i c u m i n f é r i u s) adjoins the symphysis on the bottom.

The pubic symphysis displays clear differences between the male and the female. In women this junction is smaller in height but thicker than in men. In women slight movement is possible in the pubic symphysis during child labor.
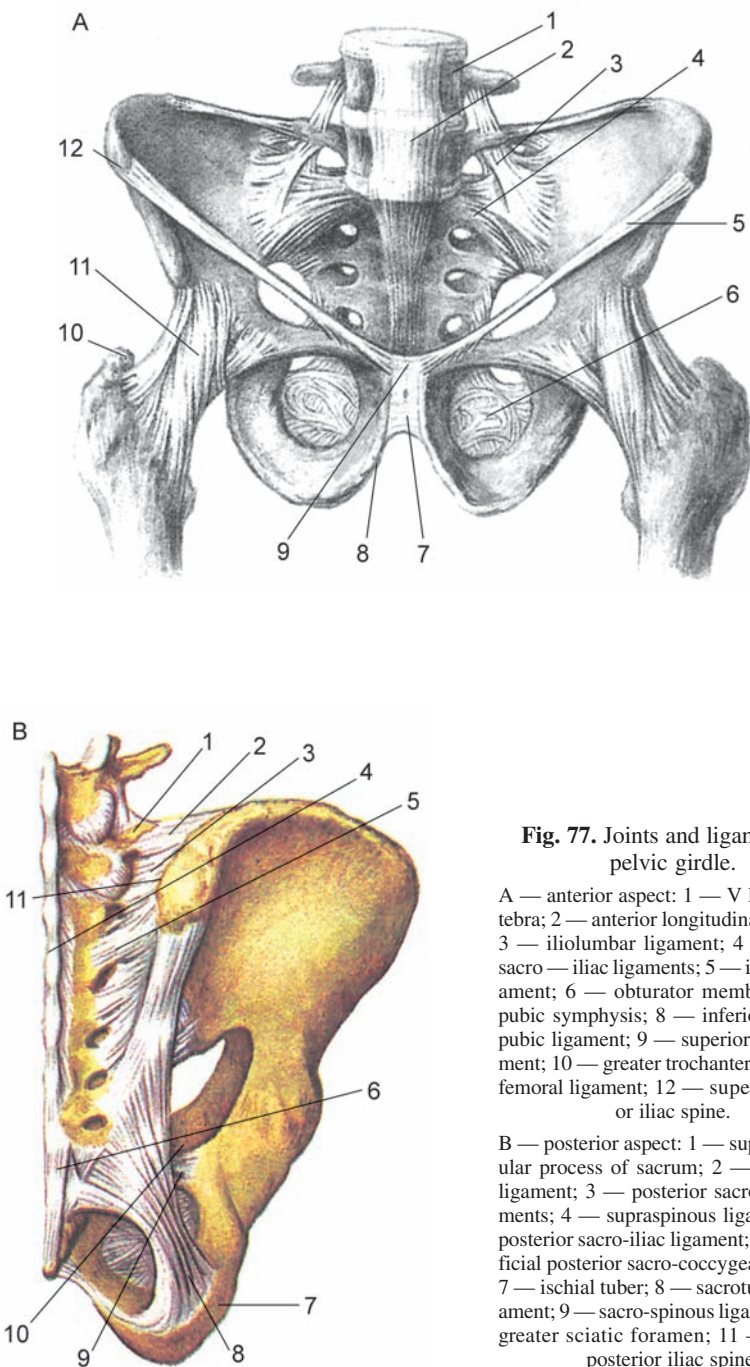
Fig. 77. Joints and ligaments of pelvic girdle.

A — anterior aspect: 1 — V lumbar vertebra; 2 — anterior longitudinal ligament; 3 — iliolumbar ligament; 4 — anterior sacro — iliac ligaments; 5 — inguinal ligament; 6 — obturator membrane; 7 — pubic symphysis; 8 — inferior (arcuate) pubic ligament; 9 — superior pubic ligament; 10 — greater trochanter; 11 — iliofemoral ligament; 12 — superior anterior iliac spine.

B — posterior aspect: 1 — superior articular process of sacrum; 2 — iliolumbar ligament; 3 — posterior sacro-iliac ligaments; 4 — supraspinous ligament; 5 — posterior sacro-iliac ligament; 6 — superficial posterior sacro-coccygeal ligament; 7 — ischial tuber; 8 — sacrotuberous ligament; 9 — sacro-spinous ligament; 10 — greater sciatic foramen; 11 — superior posterior iliac spine.

Apart from joints and articular ligaments, bones of the pelvis connect with the sacrum by two strong ligaments. The s a c r o t u b e r a l l i g a-m e n t (lig. s a c r o t u b e r á l e) stretches from the ischial tuberosity to the lateral edges of the sacrum and coccyx. The s a c r o s p i n o u s l i g a-m e n t (lig. s a c r o s p i n á l e) connects the ischial spine and the coccyx. The sacrum, which likes a wedge between the two hipbones, acts as the base of the pelvic ring. It does not get displaced forward and down in the sacroiliac joints by the weight of the trunk, because these articulations are strengthened by the interosseous sacroiliac, the sacrotuberal and the sacros-pinous ligaments.

The pelvis (as a whole)

The pelvis is formed by the two hipbones and the sacrum (Fig. 78). It resembles a bone ring, which holds in itself a number of internal or-gans. The pelvic girdle is a connection between the trunk and the lower extremities. The pelvis can be divided into two compartments — the g r e a t e r and the l e s s e r p e l v e s. These two compartments are sepa-rated by a boundary line called the pelvic brim. The pelvic brim (línea terminális) passes through promontory of the sacrum, along the arched line of the iliac bone, over the crest of the pubic bones and the upper edge of the pubic symphysis.

The greater pelvis (pélvis major) is limited in the back by the body of the L5 vertebra, and at the sides by the upper flaring portion (wing) of the ilium. The greater pelvis does not have a bone wall in the front.

The lesser pelvis (pélvis minor) is limited in the back by the pelvic surfaces of the sacrum and the ventral surface of the coccyx. Its lateral walls are formed by the internal surfaces of the hipbones (below the pel-vic brim) and the sacrospinous and sacrotuberal ligaments. The front wall of the lesser pelvis is formed by the superior and inferior rami of pubic bones and the pubic symphysis.

The lesser pelvis has an inlet and outlet apertures. The s u p e r i o r a p e r t u r e (inlet) corresponds to the pelvic brim. The outlet of the lesser pelvis (i n f e r i o r a p e r t u r e) is limited by the coccyx in the back, the sacrotuberal ligaments, rami of ischia and inferior rami of pubes from the sides, and in the front — by the pubic symphysis. The obturator foramen, located in the lateral wall of the lesser pelvis, is covered by a fibrous obturator membrane, which is a proper ligament of the pelvis. This mem-brane does not cover the obturator groove, thus forming the o b t u r a t o r c a n a l. This canal serves as a passage for vessels and a nerve from the lesser pelvis onto the femur. The lateral wall of the lesser pelvis also has
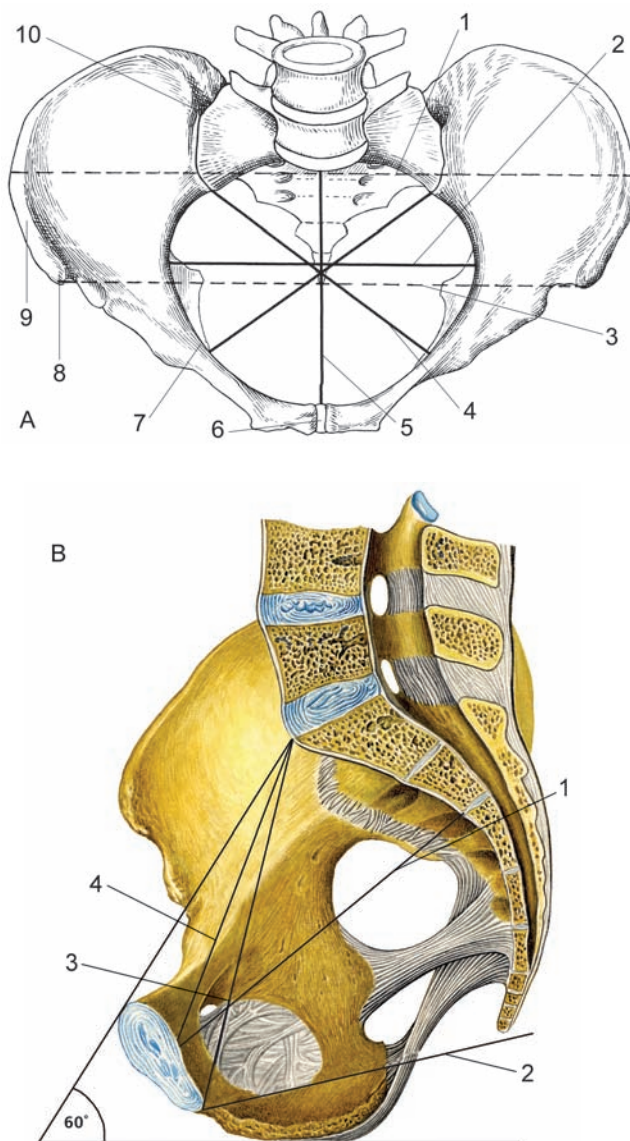
Fig. 78. Female pelvis. Dimensions of greater and minor pelvis.

A — superior aspect. 1 — distance between the iliac crests (distantia cristarum); 2 — transverse dimension; 3 — distance between anterior superior iliac spines (distantia spinarum); 4 — oblique dimension (diameter obliqua); 5 — strait dimension (true conjugate); 6 — pubic symphysis; 7 — iliopubic eminence; 8 — superior anterior iliac spine; 9 — wing of ilium; 10 — sacro-iliac joint.

B — sagittal aspect. Inner view: 1 — external conjugate; 2 — straight dimension (of its cavity); 3 — axis of pelvis; 4 — true conjugate. Dot line reveals a pitch of a pelvis (60°).

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the greater and lesser sciatic foramina. The g r e a t e r s c i a t i c f o r a -
m e n (fo r á m e n i s c h i á d i c u m m á j u s) is limited by the greater sci-
atic notch and the sacrospinous ligament. The l e s s e r s c i a t i c f o r a -
m e n (f o r á m e n i s h i á d i c u m m í n u s) is formed between the lesser
sciatic notch and the sacrotuberal and sacrospinous ligaments.

The structure of the pelvis is somewhat different in the male and fe-
male. In women, when the body is in a vertical position, the superior aper-
ture of the pelvis is positioned at a 55–60 degree angle to the horizontal
plane. The pelvis in women is wider and lower in height, and the sacrum
is wider and shorter, compared to men. The promontory of the sacrum in
women projects forwards much less, and the ischial tuberosities are more
developed, while the distance between them is greater. The angle of junc-
tion of the inferior rami of pubes is approximately 90° in the female (form-
ing the pubic arch) and 70–75° in the male (the infrapubic angle).

Knowing the sizes of the pelves in a woman is important for predict-
ing possible complications in the process of child delivery. The sizes of
both the greater and the lesser pelves have practical significance. The dis-
tance between the anterior superior iliac spines (d i s t á n t i a s p i n á r u m)
in women is 25–27 cm. The measurement between the most distant parts
of the upper flaring portion of the ilium (d i s t á n t i a c r i s t á r u m) is
28–30 cm.

The size of the inlet into the lesser pelvis, also called the true, or
obstetric, conjugate, (conjugate vera seu. gynecologica), is measured be-
tween the promontory of the sacrum and the point of the pubic symphysis
most prominent to the back. This size is approximately 11 cm. The trans-
verse diameter of the inlet of the lesser pelvis (d i á m e t e r t r a n s v é r -
s a) is the distance between the most remote points of the pelvic brim,
which is approximately 13 cm. The oblique diameter (d i á m e t e r o b l i -
q u a) of the inlet is 12 cm and is measured between sacroiliac articulation
of one side and the iliopubic eminence of the other side.

Articulations of the free lower extremity

These junctions include connections of lower extremity bones with
one another and with the hipbone (table 7).

The coxal, or hip, joint (art. cóxae) is formed between the semilu-
nar surface of the acetabulum (cotyloid cavity) and the head of femur (Fig.
79). The articular surface of the hipbone is enlarged by the a c e t a b u l a r
l a b r u m, which is a fibrocartilaginous formation, fixed onto the edge of
the acetabulum. Over the acetabular notch stretches the t r a n s v e r s e a c -
e t a b u l a r l i g a m e n t. The capsule of the hip joint attaches along the
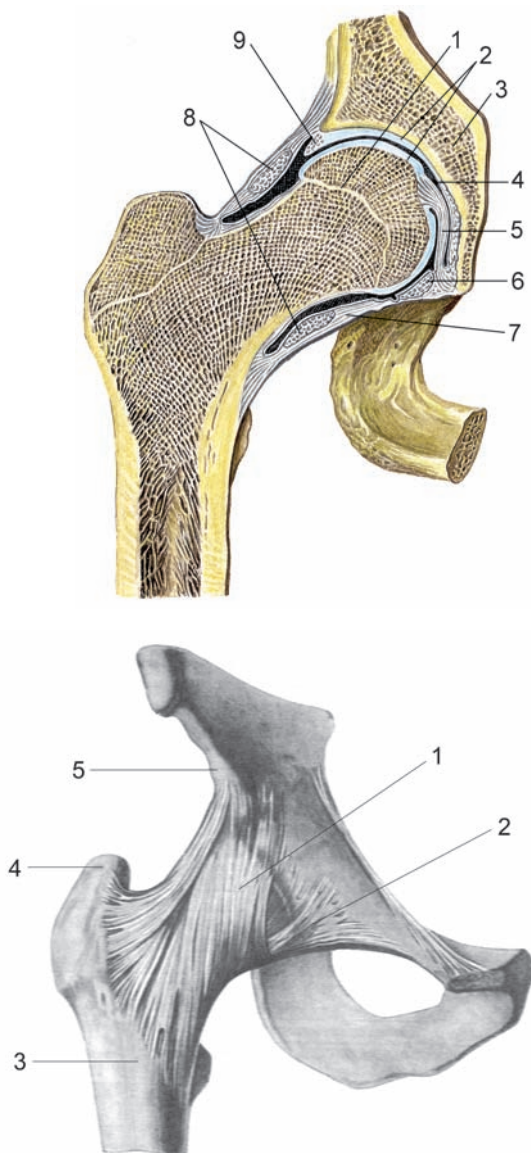edges of the cotyloid cavity. On the femur it attaches nearly along the

Fig. 79. Hip joint, right.

A — by frontal section articular cavity of hip joint is opened (acc. to R.D.Sinelnikov): 1 — epiphysial line; 2 — articular cartilage; 3 — pelvic bone; 4 — articular cavity; 5 — ligament of head of femur; 6 — transverse ligament of acetabulum; 7 — articular capsule; 8 — orbicular zone; 9 — acetabular labrum.

B — ligaments of the joint. Anterior aspect: 1 — iliofemoral ligament; 2 — pubofemoral ligament; 3 — intertrochanteric line; 4 — greater trochanter; 5 — inferior anterior iliac spine.

intertrochanteric line in the front and above the intertrochanteric crest in the back. The joint cavity is very durable and is strengthened by five strong ligaments.

Within the fibrous membrane of the articular capsule there is a thick ligament called the o r b i c u l a r z o n e (z ó n a o r b i c u l á r i s), which loops around the neck of the femur. This ligament is attached to the iliac bone below the anterior inferior iliac spine.

The i l i o f e m o r a l l i g a m e n t (l i g. i l i o f e m o r á l e), which is approximately 1 cm thick, begins on the anterior inferior iliac spine and attaches to the intertrochanteric line. The p u b o f e m o r a l l i g a m e n t (l i g. p u b o f e m o r á l e) stretches from the superior ramus of pubis and the body of the iliac bone to the medial part of the intertrochanteric line. The i s c h i o f e m o r a l l i g a m e n t (l i g. i s c h i f e m o r á l e) is situated on the posterior surface of the joint. It begins on the body of the ischial bone, stretches laterally almost horizontally, and ends by the trochanteric fossa of greater trochanter. The articular cavity, covered by a synovial membrane, contains the l i g a m e n t o f h e a d o f f e m u r, which connects the fovea capitis of femur and the bottom of the cotyloid cavity. This ligament plays a key role in keeping the head of the femur by the acetabulum during the formation of the joint.

By structure the hip joint is spheroid. Movements in this joint include flexion and extension, abduction and adduction, circumduction and rotation. Flexion and extension take place about the frontal axis, their volume depending on the position of the leg in the knee joint. Maximal flexion (approximately 120°) is carried out when the leg is bent. With a straight leg the volume of flexion is reduced to 85° because of tension of the posterior group of muscles on the hip. Extension in the coxal joint has a volume of only 13–15° due to the strong pull of the iliofemoral ligament. Abduction and adduction are carried out about the sagittal axis at amplitude of 80–90°. The total volume of rotation about the vertical axis is up to 40–50°. The overall degree of movement in the hip joint is less compared to the shoulder joint. The hip joint, however, is more durable, strengthened by strong ligaments and muscles.

The knee joint (art. génus) is the largest and most complicated joint (Fig. 80 and 81). It is formed by the femur, tibia and patella. The articular surfaces of the medial and lateral condyles of the femur articulate with the superior articular surface of the tibia and with the patella.

The joint contains intra-articular semilunar cartilages called m e n i s c i, which increase the congruence of articular surfaces, and also act as shock absorbers. The outer sides of the menisci are fused with the articular capsule. The inner edges are thin and are attached to the intercondylar
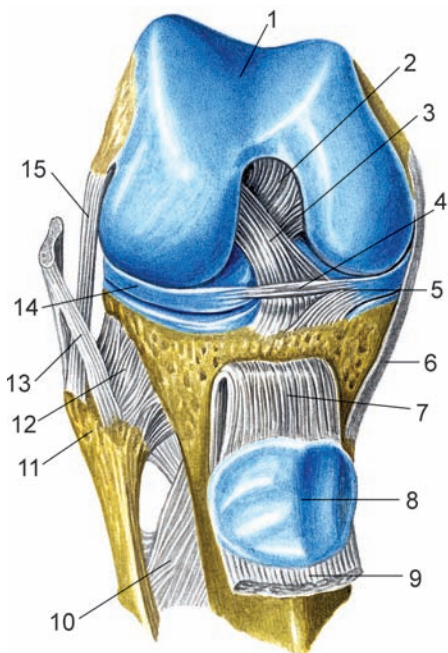
Fig. 80. Knee joint, right. Anterior aspect. Articular capsule removed, tendon of m. quadriceps femoris with patella are pulled down.

1 — articular surface; 2 — posterior cruciate ligament; 3 — anterior cruciate ligament; 4 — transverse ligament of knee; 5 — medial meniscus; 6 — tibial collateral ligament; 7 — patellar ligament; 8 — articular surface of patella; 9 — tendon of m. quadriceps femoris; 10 — interosseous membrane of leg; 11 — head of fibula; 12 — anterior ligament of head of fibula; 13 — tendon of m.biceps femoris; 14 — lateral meniscus; 15 — fibular collateral ligament.

eminence of the tibia. The front edges of the menisci are interconnected by the t r a n s - v e r s e l i g a m e n t o f t h e k n e e (l i g. t r a n s v é r s u m g é n u s).

The articular capsule of the knee joint is thin. On the femur it attaches approximately 1 cm. away from the edges of the articular surfaces. On the tibia and patella the joint capsule is attached along the margins of articular surfaces. The synovial membrane forms several folds, which are filled by adipose tissue. The largest of these are the paired alar folds, located on either side of the patella.

The knee joint is strengthened by several tough ligaments. The f i b u l a r c o l l a t e r a l l i g a m e n t (l i g. c o l l a t e - r á l e f i b u l á r e) stretches from the lateral epicondyle of the femur to the lateral surface of the head of the fibula. The t i b i a l c o l l a t e r a l l i g a m e n t (l i g. c o l l a t e r á l e t i b i á l e) is accreted with the capsule; it begins on the medial epicondyle of femur and attaches to the upper part of the medial margin of the tibia.

On the posterior surface of this joint is the o b l i q u e p o p l i t e a l l i g a - m e n t (l i g. p o p l í t e u m o b l í q u u m), which begins on the medial condyle of the tibia and attaches on the posterior surface of the femur below the lateral epicondyle. The a r c u a t e p o p l i t e a l l i g a m e n t (l i g. p o p l í t e u m a r c u á t u m) begins on the posterior surface of the head of the fibula, curves medially and attaches to the posterior surface of the tibia. In the front the articular capsule is strengthened by the tendon of the quadriceps femoris muscle, which is also called the p a t e l l a r l i g a m e n t. The

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lateral and medial fascicles of this tendon pass from the patella onto the lateral and medial epicondyles of the femur, and are called the medial and lateral patellar ligaments (retinaculi patellae mediale et laterale).

The articular cavity of the knee joint contains two cruciate ligaments (Fig. 80, 81). The anterior cruciate ligament (lig. cruciátum antérius) begins on the medial surface of the lateral epicondyle of the femur and attaches to the anterior intercondylar field of the tibia. The posterior cruciate ligament (lig. cruciátum postérius) stretches between the lateral surface of the medial epicondyle of femur and the posterior intercondylar field of the tibia. The arcuate ligaments are covered by the synovial membrane. The knee joint has several synovial bursae (búrsae synoviáles). Their numbers and sizes may vary between individuals.

The knee joint is a complex (contains menisci) compound joint, condyloid according to the shape of its artic-

Fig. 81. Knee joint. Posterior aspect.

1 — fibular collateral ligament; 2 — arcuate popliteal lidament; 3 — popliteus (partly removed); 4 — interosseous membrane; 5 — «deep goose's-foot»; 6 — tibial collateral ligament; 7 — tendon of semimembranosus; 8 — oblique popliteal ligament.

ular surfaces. It can undergo flexion and extension about the frontal axis with the total volume of 150°. Rotation about the vertical axis is possible when the leg is bent as a result of relaxation of the collateral ligaments. The volume of rotation is approximately 15°, and of passive rotation — 35°. The cruciate ligaments prevent pronation of the leg but become relaxed during supination. Supination is inhibited mainly by tension of the collateral ligaments, and pronation — by the cruciate ligaments and the tendon of quadriceps femoris muscle.
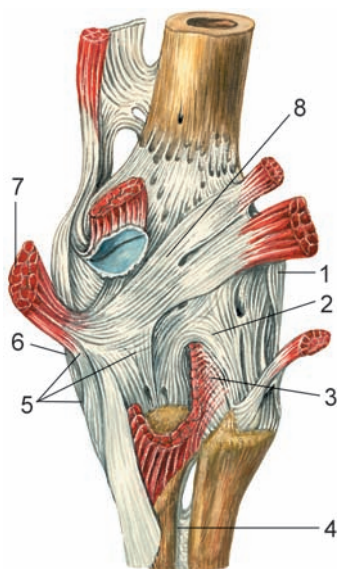
Articulations of the bones of the leg

Bones of the leg are connected by the tibiofibular joint and also by continuous fibrous connections, which include the tibiofibular syndesmosis and the interosseous membrane of the leg.

The tibiofibular joint (art. tibiofibuláris) is formed between the fibular articular surface of the tibia and the articular surface on the head of the fibula. The articular surfaces are flat. The articular capsule is taut; it is strengthened by the anterior and posterior ligaments of the fibular head (ligg. cápitis fíbulae antérius et postérius).

The tibiofibular syndesmosis (syndesmósis tibiofibuláris) is a continuous fibrous connection between the fibular notch of the tibia and the corresponding articular surface on the lateral malleolus of the tibia. In the front and back the tibiofibular syndesmosis is strengthened by the anterior and posterior tibiofibular ligaments (ligg. tibiofobulária antérius at postérius). In some cases the capsule of the talocrural joint protrudes into this syndesmosis, in which case it could be considered a joint.

The interosseous membrane of the leg (membrána interóssea crúris) is a continuos connection in the form of a strong connective membrane, stretched between interosseous margins of the tibia and fibula.

Articulations of the bones of the foot

The bones of the foot form articulations with the leg (the talocrural joint), articulations of the tarsus, metatarsus and phalanges. All these joints are fixated by the numerous ligaments (Fig. 82).

The ankle joint (art. talocrurális) is a compound hinge joint, formed between the inferior articular surface of the tibia and the articular surfaces of the trochlea of the talus and the medial and lateral malleoli. The fibula and tibia brace the trochlea of the talus like a fork. The articular capsule is attached from behind and the sides to the edges of articular surfaces and 0.5 cm away from them in the front. There are ligaments on the side surfaces of the joint. On the lateral part of the joint there are anterior and posterior talofibular and the calcaneofibular ligaments. They all begins on the lateral malleolus and spread out in a fan-like fashion. The anterior talofibular ligament (lig. talofibuláre antérius) stretches to the neck of the talus, while the posterior talofibular ligament — to the posterior process of the talus. The calcaneofibular ligament (lig. calcaneofibuláre) stretches down and ends on the outer surface of the calcaneus. On the medial surface of the talocrural joint there is the medial (deltoid) ligament (lig. collaterale mediále, seu deltoídeum). It begins on the medial malleolus, divides into four part and attaches to the navicular bone, talus and calcaneus.
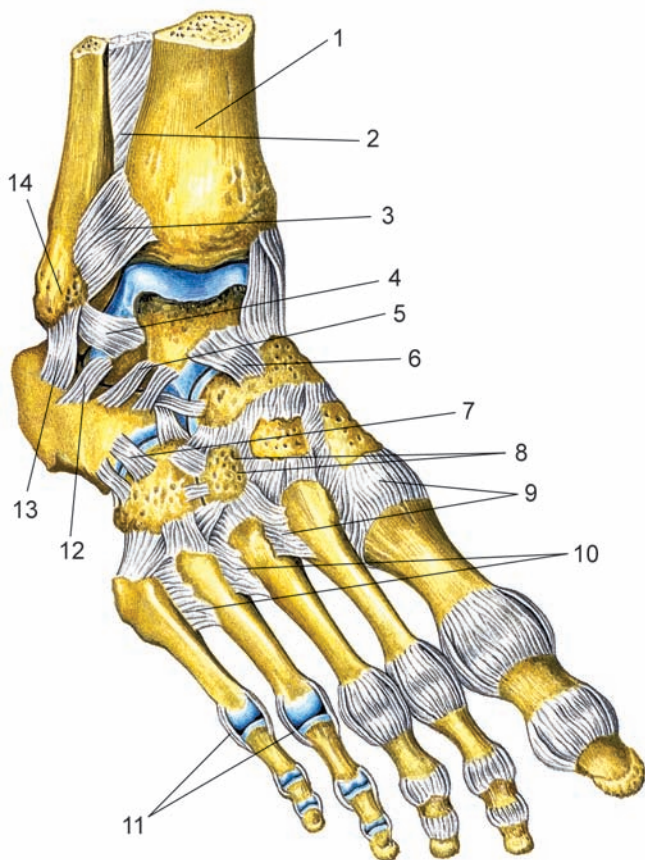
Fig. 82. Joints and ligaments of foot, right one. Superior and right aspects.

1 — tibia; 2 — interosseum membrane of leg; 3 — anterior tibiofibular ligament; 4 — anterior talofibular ligament; 5 — interosseum talocalcaneum ligament; 6 — calcaneonavicular ligament; 7 — calcaneocuboid ligament; 8 — dorsal tarsal ligaments; 9 — dorsal tarsometatarsal ligaments; 10 — dorsal metatarsal ligaments; 11 — collateral ligaments; 12 — lateral talocalcaneal ligament; 13 — calcaneofibalar ligament; 14 — lateral malleolus.

These are called the t i b i o n a v i c a l a r, t i b i o c a l c a n e a l and the a n t e - r i o r and p o s t e r i o r t i b i o t a l a r p a r t s of the medial ligaments.

Possible movements in the talocrural joint are plantar (flexion of the foot down) and extension (dorsal flexion) about the frontal axis with the total volume of approximately 70°. When the foot is flexed slight movements to the sides are also possible.

Articulations of the tarsus include the subtalar, talocalcaneonavicular, transverse tarsal, calcaneocuboid, cuneonavicular, and tarsometatarsal joints.

The subtalar joint (art. subtaláris) is formed by the posterior talar articular surface of the calcaneus and the posterior calcaneal articular surface of talus. The articular surfaces are congruent. The joint performs movements about the sagittal axis.

The talocalcaneonavicular joint (art. talocalcaneonavicularis) is formed by articular surface of the head of talus, the navicular bone in the front and the calcaneus underneath. The articular capsule attaches along the edges of articular surfaces and is strengthened by several ligaments. The talocalcaneal interosseous ligament (lig. talocalcáneum interósseum) is very strong and is situated in the tarsal sinus between sulci of the calcaneus and talus. The plantar calcaneonavicular ligament (lig. calcaneonaviculáre plantáre) connects the inferior medial part of the sustentaculum tali and inferior surface of the navicular bone. The talonavicular ligament (lig. talonaviculáre) connects the dorsal surfaces of the neck of the talus and the navicular bone.

The movements in this joint, together with subtalar joint, are made about the sagittal axis. During abduction and adduction (eversion and inversion) the talus is fixated. Movement of the navicular and calcaneal bones causes displacement of the whole foot. During adduction of the foot its medial margin rises, while the back of the foot turns somewhat laterally. During abduction the lateral margin rises, and the back of the foot shifts medially. The total volume of movements about the sagittal axis does not exceed 55°.

The calcaneocuboid joint (art. calcaneocuboídea) is formed by adjacent articular surfaces of the calcaneus and the cuboid bones. This is a saddle joint with congruent articular surfaces and a limited degree of movement. The articular capsule is strengthened by the long plantar ligament (lig. plantáre lóngum). This ligament begins on the inferior surface of the calcaneus, spreads out to the front like a fan and attaches to the bases of II–V metatarsal bones. Next to it is a short durable calcaneocuboid ligament (lig. calcaneocuboídeum).

For practical reasons the calcaneocuboid and the talonavicular joints (which are part of the talocalcaneonavicular joint) are considered as **the transverse tarsal joint (art. tarsi transversa)**, or Chopart's joint. Apart from the ligaments strengthening each of the two articulations, Chopart's joint has a common bifurcate ligament (lig. bifurcátum), which consists of two parts. The bifurcated ligament begins on the upper lateral margin of the calcaneus. One of its parts attaches to the posterior lateral margin of the navicular bone, and the other — to the back of the cuboid bone. When the bifurcated ligament is dissected, the structure of

the foot looses its stability. This ligament is therefore called the key of the Chopart's joint.

The cuneonavicular joint (art. cuneonaviculáris) is formed between plane articular surfaces of the navicular bone and three cuneiform bones. The articular capsule attaches along the edges of articular surfaces. The joint is strengthened by numerous ligaments, including the plantar and dorsal cuneiform ligaments, interosseous intercuneiform ligaments, the plantar and dorsal intercuneiform ligaments. Movement in this joint is very slight.

The tarsometatarsal joints (art. tarso-metatarsáles), or Lisfranc's joints, are formed between the plane articular surfaces of the navicular and cuneiform bones and the metatarsal bones. These articulations include three independent, isolated joints: the junction of the medial cuneiform and I metatarsal bone; junction of II and III metatarsal bones with the intermediate and the lateral cuneiform bones; and articulation between the cuboid bone with the IV and V metatarsal bones. The articular cavities do not communicate among themselves. The capsules are attached along the edges of articular surfaces. They are strengthened by the dorsal and plantar tarsometatarsal ligaments (ligg. tarsometatarsália dorsália et plantária). The intra-articular interosseous cuneometatarsal ligaments are also considered important. The medial interosseous cuneometatarsal ligament, which connects the medial cuneiform bone and the base of the II metatarsal bone, is called the key of the Lisfranc's joint. There is only slight movement possible in these joints.

The intermetatarsal joints (artt. intrmetatarsáles) are formed between adjacent bases of metatarsal bones. The articular surfaces are strengthened by transverse dorsal and plantar metatarsal ligaments (ligg. metatarsália dorsália et plantária). Between the articular surfaces, in the articular cavities there are metatarsal interosseous ligaments (ligg. metatarsália interossea). Movement in the intermetatarsal joints is very limited.

The metatarsophalangeal joints (artt. metatarsophalageae) are formed between heads of the metatarsal bones and bases of the proximal phalanges. The articular surfaces of the phalanges are almost spherical, while the articular fossae of the metatarsal bones are oval in shape. The thin articular capsule is strengthened at the sides by collateral ligaments and at the bottom by the plantar ligaments. The heads of the metatarsal bones are connected by the deep transverse metatarsal ligament (lig. metatarsále transversum profundum), which accretes the capsules of all metatarsophalangeal joints. Move-

Table 7. Joints of the lower extremities.

Joint	Articular surfaces	Type of joint	Axes of rotation	Movement in joint
Sacro-iliac joint	Auricular surfaces of ilium and sacrum	Flat	Multiaxial	Immovable
Coxal (hip) joint	Semilunar surface of acetabulum (and acetabular labrum) and head of femur	Spherical (ball and socket)	Multiaxial	Flexion-extension, abduction-adduction, rotation and circumduction of femur
Knee joint	Condyles and patellar surface of femur, upper surface of tibia and articular surface of patella	Trochlear; compound; complex	Biaxial	Flexion and extension of leg; rotation of the leg when it is bent
Tibiofibular joint	Articular surfaces of tibia and fibula	Flat	Multiaxial	Slightly movable
Tibiofibular syndesmosis	Fibular notch of tibia and articular surface of head of fibula	Continuous joint		Slightly movable
Talocrural (ankle) joint	Medial and lateral malleoli, inferior surface of tibia, trochlea of talus	Trochlear; compound	Uniaxial	Dorsiflexion and plantar flexion of foot
Subtalar joint	Posterior calcaneal facet of talus and posterior talar surface of calcaneus	Cylindrical (pivot), combination	Uniaxial	
Talocalcaneo-navicular joint	Navicular and calcaneal (anterior and posterior) facets of talus; anterior and middle talar facets of calcaneus; and posterior articular facet of navicular bone	Spherical; compound; combination	Multiaxial	Movement in these joints is combined: pronation (inversion) and supination (eversion) of the foot

| Calcaneocuboid joint | Cuboid articular facet of calcaneus and posterior articular facet of cuboid bone | Saddle | Biaxial | Slight rotation about the sagittal axis |
Cuneonavicular joint	Posterior articular facets of three cuneiform bones and anterior articular facet of navicular bone	Flat	Multiaxial	Limited movement
Tarsometatarsal joints	Anterior articular facet of three cuneiform bones and navicular bone, and bases of metatarsal bones	Flat	Multiaxial	Limited movement
Intermetatarsal joints	Adjoining articular facets of metatarsal bones	Flat	Multiaxial	Limited movement
Metatarsophalangeal joints	Heads of metatarsal bones and bases of phalanges	Ellipsoidal	Biaxial (about sagittal and frontal axes)	Flexion-extension and abduction-adduction of phalanges
Interphalangeal joints	Heads and bases of neighboring phalanges	Trochlear	Uniaxial (frontal)	Flexion and extension of phalanges

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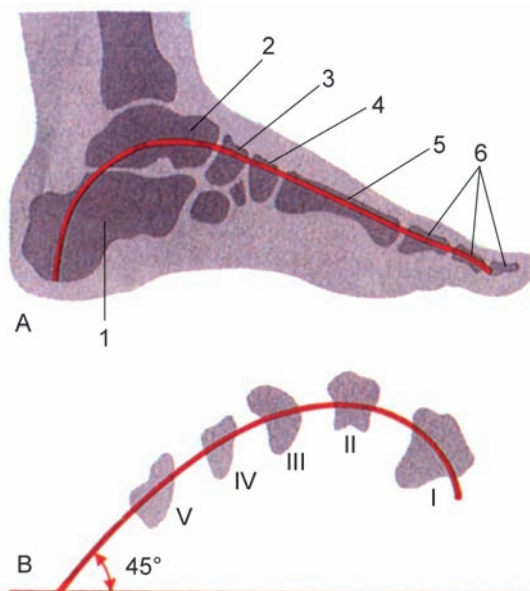
Fig. 83. Structure of arches of foot**.**

A — longitudinal arch; 1 — calcaneus; 2 — talus; 3 — navicular; 4 — intermediate cuneiform; 5 — II metatarsal bone; 6 — phalanges of 2nd digit.

B — transverse arch: I — V — transversal cut of metatarsal bones.

ments in these joints are flexion and extension about the frontal axis, with the total volume of 90°. Abduction and the adduction about the sagittal axis are possible only within a limited volume (table 7).

The interphalangeal joints of foot (artt. interphalangeae pedis) are hinge joints. They are formed between bases and heads of neighboring phalanges of the foot. They have loose articular capsules, attached along the edges of articular surfaces. The capsules are strengthened by the p l a n t a r and the c o l l a t e r a l l i g a m e n t s. The interphalangeal joints carry out flexion and extension about the frontal axis with the total volume of these movements no more than 90°.

Characteristics of the joints of the lower extremities are demonstrated in the table 7.

The foot as a whole

The foot is adapted for creating support. This is determined by the presence of tight joints and durable ligaments. The joined bones of the foot form several l o n g i t u d i n a l and t r a n s v e r s e a r c h e s (Fig. 83).

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Five longitudinal arches begin at the calcaneus and spread in fan-like fashion forward to the heads of metatarsal bones. At the level of the highest points of the longitudinal arches is the transverse arch. Due to the structure of these arches the foot rests on three main points of support instead of its whole surface. These points are the calcaneal tuber in the back, and heads of the I and V metatarsal bones in front.

The arches of the foot are supported by the shape and arrangement of the bones and by ligaments (these are so-called passive supports), and by muscle tendons (active supports). The strongest support of the longitudinal arches are the long plantar, the plantar calcaneonavicular and some other ligaments. The transverse arch of the foot is strengthened by the deep transverse metatarsal ligament and other ligaments stretched in the transverse direction.

Muscles and their tendons, that are oriented in the longitudinal direction, actively strengthen corresponding arches, while muscles and tendons oriented transversally strengthen the transverse arch. If the active and passive supports become relaxed, the arches of the foot will lower resulting in a «flat foot», or «fallen arch».

Questions for revision and examination

1. Why is the sacrum considered the «key» of the pelvic ring? What type of articulations is formed between the sacrum and the hipbones?

2. Name the sizes of the greater and lesser pelves. What practical importance to they have?

3. What differences (in structure) are there between the coxal and the shoulder joints?

4. What ligaments support the knee joint? Where are these ligaments situated and how do they influence movement in this joint?

5. Where is the subtalar joint located and what is its structure?

6. Which joint is called the transverse joint of the foot? What ligament acts as the «key» of this joint?

7. Name the arches of the foot. What formations serve as active and passive supports of these arches?

THE MUSCULAR SYSTEM

Skeletal muscles are attached to bones and, by contracting, cause them to move (Fig. 84). Muscles participate in formation of body cavities and have influence upon organs of sight, hearing and equilibrium. They help to retain the body in balance, provide support and movement, accomplish respiration and swallowing and perform facial gestures. Muscles compose approximately 20–22 percent of total body weight in a newborn, up to 40 percent in an adult and 25–30 percent in senile age. The human body contains about 400 muscles, which contract voluntarily, when a person wills them to.
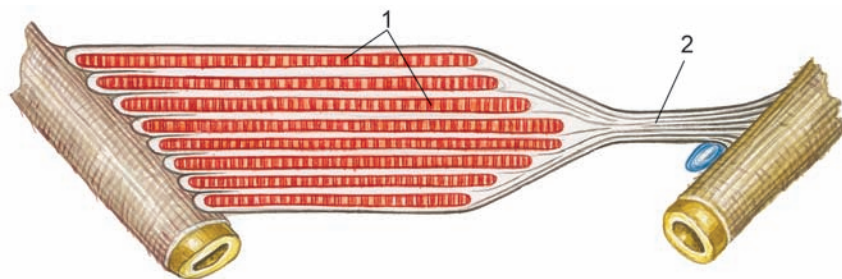
Fig. 84. Beginning and attachment of a muscle**.**
1 — muscular bundles; 2 — tendon.

STRUCTURE OF THE SKELETAL MUSCLES

The principle elements of the skeletal muscles are striated muscle fibers. These fibers are surrounded by loose connective tissue called e n - d o m y s i u m. Bundles, or fascicles, of fibers are separated from one another by connective tissue layers called perimysium, and the whole muscle is surrounded by the e p i m y s i u m (o u t e r   p e r i m y s i u m). Loose connective tissue found in muscles performs functions of support and demarcation between functional elements. It also holds the blood vessels, which nourish muscle fibers, and nerves.

The length of muscle fibers varies from several millimeters to 12.5 cm (in the sartorius muscle), and its thickness—from 9 to 100 mm. In short muscles the length of fibers may be equal to the length of the muscle, while in long muscles it is much shorter.

Muscle fibers form the fleshy part of the muscle called the v e n t e r, which continues into the muscle t e n d o n. The muscle fascicles or the tendon attach to bones. Tendons consist of dense connective tissue, which are rich in collagen fibers and are formed as a continuation of muscle connective tissue elements into the periosteum. Tendons of different muscles vary in structure. Muscles of extremities have long tendons, muscles of abdominal walls have broad flat tendons called a p o n e u r o s i s. Some muscles have an intermediate tendon, which divides the muscle into two venters. Muscle fibers are some muscles (the straight muscle of abdomen) are interrupted by tendon partitions (short tendons). Tendons are considerably thinner than muscles, but possess very high durability.

CLASSIFICATION OF MUSCLES

There are several ways of classification of skeletal muscles. Muscles can be classified according to topography, shape, orientation of fibers, function and position relative to joints. They are divided into superficial and deep, lateral and medial, and internal and external.

Muscles can be of many possible shapes (Fig. 85). Walls of the abdomen are formed by broad strap muscles. Fusiform muscles are typical for the extremities. They attach to bones and move them like levers. Fascicles in a fusiform muscle are oriented parallel to its longitudinal axis. Muscles in which fiber fascicles are situated only on one side of the tendon are called unipennate. If they are situated on two sides, the muscle is called bipennate. And if fascicles extend from several sides of the tendon, the muscle is called multipennate.

Some muscles have two or more heads of origin, which connect with each other into a common venter that continues into one insertion tendon. These are named according to the number of their heads, for example, biceps, triceps, etc. There are also muscles, which have a common venter and several points of attachment (e.g. the extensor muscle of fingers). Some muscles have a circular fiber arrangement. These usually surround natural
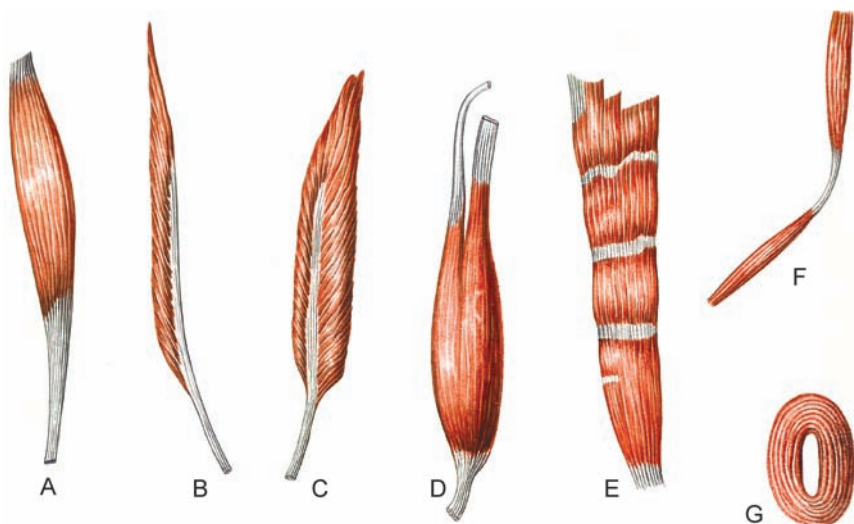

Fig. 85. Forms of muscles.

A — fusiform muscle; B — unipennate muscle; C — bipennate muscle; D — two-headed muscle; E — strap (band-shaped) muscle; F — two-bellied muscle; G — sphincter.

openings and are called sphincters. There are also muscles with radial fiber arrangement found around openings (dilator muscles).

Many muscles of the body are named according to their shape. Thus, there is a rhomboid muscle, the orbicular muscles, etc. Some muscles were named based on the orientation of their fibers (transverse muscle of the abdomen) or according to their function (levator scapulae muscle, pronator teres, pronator quadratus, etc).

Muscles can be divided into groups according to their association with joints. They can bear influence upon only one joint (monoarticular) or two or more joints (biarticular and multiarticular). Some muscles have a point of origin on a bone, and insert into the skin without passing over any joints (muscles of facial expression, ets.)

Finally, muscles are divided according to function into synergists and antagonists. Synergists are muscles, which cause movement in the same direction, while antagonists cause movement in opposite directions.

THE AUXILIARY APPARATUS OF MUSCLES

The work of muscles is directed by specialized anatomic formations that compose the auxiliary apparatus of muscles. These include fasciae, fibrous canals, tendon sheaths, synovial bursae and trochleae of muscles.

Fasciae are connective tissue encasements of muscles. They separate muscles from each other, support them during contraction, and for some muscles they serve as a point of origin. In pathological processes fasciae can restrict the spreading of pus or blood (during hemorrhage). Fasciae are divided into superficial and deep. Superficial fasciae are situated beneath the skin separating muscles from subcutaneous fat. Deep fasciae are situated between adjacent muscle layers. There are, 0sually, intermuscular partitions between groups of muscles with different functions. These begin on a superficial or deep fascia and attach to the periosteum. In places, where fasciae are connected to each other, and which undergo considerable pressure, there are often thickenings of the fascia called f a s c i a l n o d e s. These nodes usually contain blood vessels and nerves. Another example of fascial thickenings are tendon arcs, which pass over neurovascular bundles or tendons. Fasciae can have thickening in regions of joints, forming retinacula of tendons. Retinacula are usually attached to bone protrusions and serve to fix tendons in a certain position, preventing their displacement during muscle contraction.

Between retinacula of muscles and underlying bones there are **osteofibrous or fibrous canals**, divided into sectors with connective tissue partitions. These canals contain s y n o v i a l t e n d o n s h e a t h s (Fig.

86, 87). The visceral part of a s y n o v i a l   s h e a t h directly lines the tendon, while the parietal part fuses with the wall of the canal. The visceral and parietal layers continue into each other at the end of the sheath and along the length of the sheath, forming a mesotendinium. The mesotendinium contains vessels and nerves, which nutrify the tendon. During muscle contraction, the visceral part of the sheath moves with the tendon. The two parts slide easily against one another, because the tendon sheath cavity contains synovial fluid, which eliminates friction (Fig. 88).

Tendons of some muscles contain **sesamoid bones** in the region of a joint. These serve to increase the angle between the tendon and the bone. The largest sesamoid bone found in the body is the patella. Sometimes there is a synovial bursa situated between the bone and the muscle, tendon or skin, which decreases friction and eases the sliding of the muscle. On the outside the wall of the
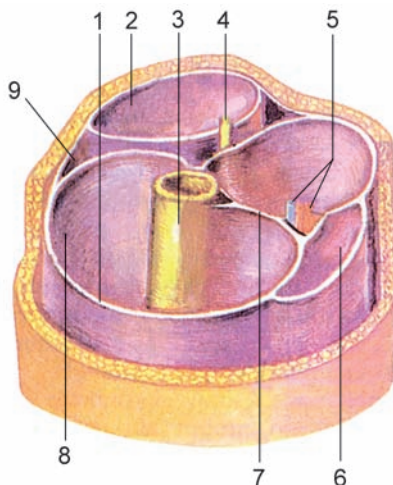

Fig. 86. Tendinous sheaths of muscles within the lower 1/3 of right thigh.

1 — fascia lata; 2 — fascial vagina of flexors; 3 — femur; 4 — sciatic nerve; 5 — femoral artery and vein; 6 — fascial vagina of m.sartorius; 7 — medial femoral intermuscular septum; 8 — bone-fascial vagina of m.quadriceps femoris; 9 — lateral femoral intermuscular septum.
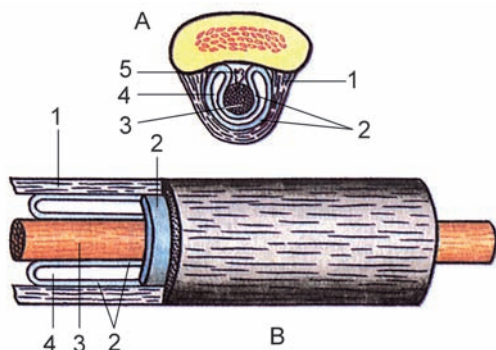

Fig. 87. Synovial sheath of tendon**.**
A — transverse section; B — longitudinal section. 1 — fibrous sheath; 2 — synovial sheath; 3 — tendon; 4 — synovial cavity; 5 — mesotendon.
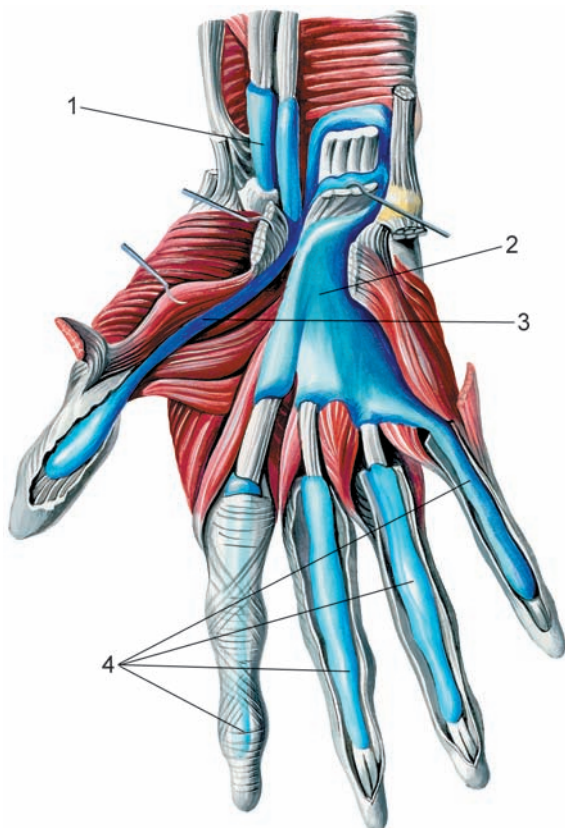
Fig. 88. Synovial sheath of hand.

1 — tendinous sheath of flexor carpi radialis; 2 — common flexor sheath; 3 — tendinous sheath of m. flexor pollicis longus; 4 — synovial and fibrous sheaths of tendos of fingers.

bursa is covered with a fibrous membrane, while the cavity of the bursa is lined with a synovial membrane. The size of the bursae varies from several millimeters to several centimeters. The cavity of the bursa sometimes communicates with an articular cavity. Next to their point of attachment, tendons of some muscles pass over a bony prominence called a trochlea. Trochleae change the direction of the tendon, provide support and increase the angle of attachment of the tendon to the bone. By this it increases the force applied during contraction of the muscle.

WORK OF MUSCLES

The work of a muscle depends on its size, shape and structure. A single muscle fiber can develop a force of approximately 0.1–0.2 g. An
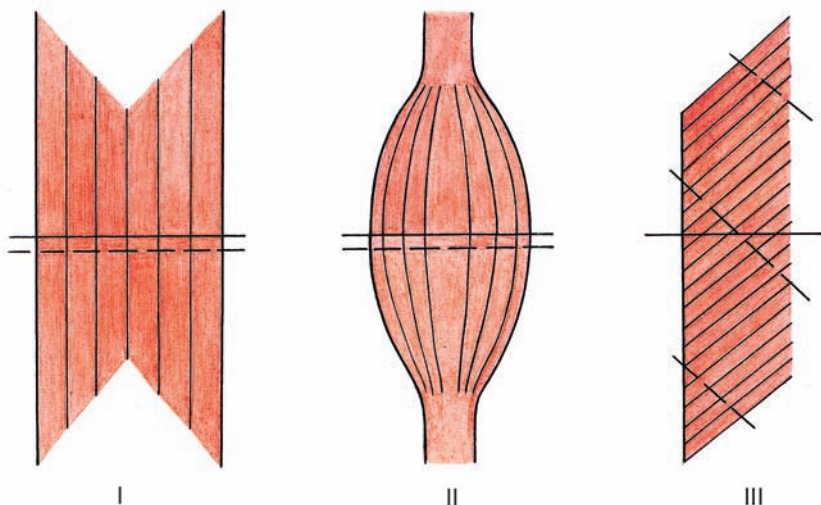
Fig. 89. Anatomic (continuous line) and physiologic (dot line) diameters of muscles of various shapes.

I — flat muscle; II — fusiform muscle; III — unipennate muscle.

absolute force produced by a muscle is on the average 10 kg per 1 mm^2, and varies for different muscles between 6.24 and 16.8 kg/mm^2. The strength of a muscle is directly proportional to the number of muscle fibers. The total area of all muscle fibers on a transverse section, cut perpendicularly to the long axis of the muscle, is called the a n a t o m i c a l c r o s s s e c t i o n (Fig. 89).

The size of the p h y s i o l o g i c a l c r o s s - s e c t i o n depends on the structure of the muscle. The more fibers there are per unit on the transverse cut, the greater is the physiological cross section. Unipennate and bipennate muscles, which have a large number of short fibers obliquely attached to the tendon, have a greater physiological cross section than strap or fusiform muscles of the same size. The long muscle fibers of strap and fusiform muscles are parallel to their longitudinal axis, so the force of contraction is directly proportional to the length of the muscle. The force of contraction also depends on where the muscle is attached to the bone lever. It decreases as the point of attachment approaches the pivot joint; the speed of muscle movement, however, becomes increased. The force of contraction grows as the angle of attachment between bone and tendon approaches 90°. This also causes the useful component of muscle force to increase. The work of a muscle is also determined by the area of its origin. If this area is large, the work of the muscle is increased. If the point of origin is small, the muscle can do less work, but its movements can be quicker and more delicate.
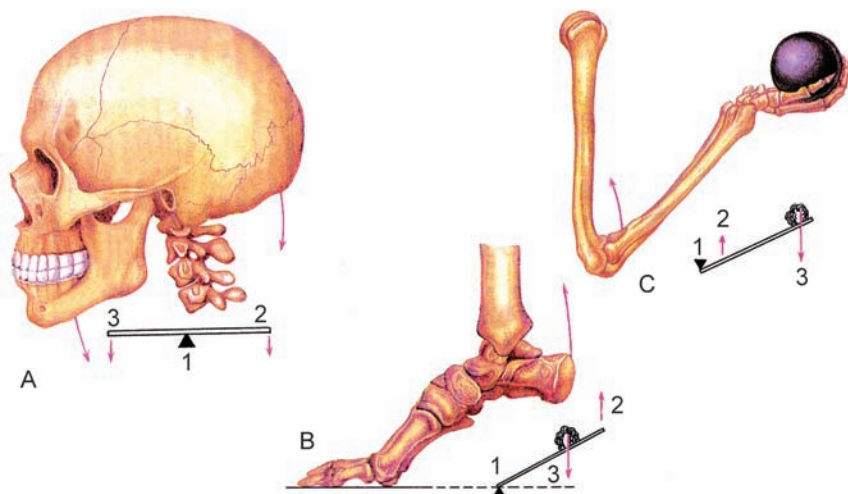
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Fig. 90. Action of muscles upon various levers.
A — lever of balance; B — lever of strength; C — speed lever. 1 — pivot point; 2 — point of applying; 3 — point of resistance.

Based on the nature of their movement, muscles are divided into «strong» and «fast» (Fig. 90). «Strong» muscles have a large physiological cross section, large areas of insertion, distanced from the pivot joint, and well-developed intramuscular connective tissue. For example, the gluteus and soleus muscles. «Fast» muscles have small areas of origin and insertion, which are close to the pivot joint. Their physiological cross section is small, the intramuscular connective tissue is poorly expressed, and muscle fibers are relatively long. «Fast» muscles contract with greater speed and amplitude, but less force. Also, they become tired more quickly than «strong» muscles. Examples of «fast» muscles are the biceps and sartorius.

During contraction, the origin and insertion points of the muscle move closer to each other, bringing into movement the bones they are attached to, and thus carrying out work. Therefore, by contraction of appropriate muscles, the human body and its parts change their position, move, resist or succumb to gravity. Contraction of muscles also serves for holding the body in a static position. Accordingly, muscle work can be divided into overcoming, yielding and fixating.

Overcoming work is carried out when muscle contraction changes the positions of the body or its part, with or without an extra load, moving it against gravity.

Work is called yielding when muscle force succumbs to the force of weight of the body part (extremity) or a load. The muscle is carrying out work, but its length increases instead of decreasing. An example of this is when the load on a muscle is heavier than it is capable of lifting or holding in place. In this case the load is lowered, even though the muscle is exerting force.

Fixating work is carried out when the force of contraction is used to hold a load in a certain position, without displacement. For example, when a person is standing or sitting still or holding an object. The force of muscle contraction is equal to the gravity force of the body or the object. In this case the length of the muscle is not changing (isometric contraction).

Overcoming and yielding types of work are also called dynamic work, since the force of muscle contraction is causing the body or its parts to move. Fixating work is also called static, because there is no movement-taking place.

Bones, which are connected by joints, are moved by muscles like levers. According to biomechanics, when the application of force and the resistance are takes place on different sides of the pivot point, or fulcrum, the system is called a first-class lever. In a second-class lever both forces are applied on the same side of the fulcrum, but at a different distance from it.

A first-class lever is a two-armed system, and is also called a «balance lever». The fulcrum is situated between the applied force (from muscle contraction) and the resistance point (weight of body part or load). An example is the connection between the vertebral column and the skull. The latter is in balance when the torque applied (product of force applied to the occipital bone and distance between the point of force application and the fulcrum) is equal to the torque created by weight of the head (product between the weight and the length of the lever arm, which is the distance between the weight and fulcrum).

A second-class lever is a one-armed lever. There are two types of second-class levers, depending on where the force application and resisting weight are situated relative to each other. The first type is considered to be a power lever. In such a system the lever arm of force application is longer than that of the weight resistance. An example of this is the foot, in which the heads of metatarsal bones serve as the pivot point, the force is applied at the calcaneus (by the triceps of the leg), and the weight of the body acts upon the talocrural joint. This lever system has an advantage in power, but a disadvantage in speed. The other type of one-armed system (otherwise called a third-class lever) is considered a speed lever. The lever arm force in this system is shorter than the lever arm of the counteracting weight. In case of the elbow joint, much greater force is required from the flexor muscles for acting upon the weight, which is situated at a considerable distance from

the fulcrum. This lever has an advantage in speed and amplitude of movement of a longer lever, but there is a disadvantage in power.

DEVELOPMENT OF MUSCLES

The origin of skeletal muscle in embryogenesis is the middle embryonic layer called mesoderm, which contains somites. The dorsomedial section of a somite, called the myotome. Initially contains a cavity — the myocele. As the myotome grows and turns into a syncytium mass, its cavity gradually disappears. Then, the cell mass differentiates into striated muscle fibers with a metameric arrangement. The myotome divides into cylindrical sections of muscle fibers. The dorsal sections of myotomes form the deep (proper) muscles of the back. The ventral sections form the deep muscles of the chest and anterior and lateral abdominal walls.

Muscles of the head and some muscles of the neck are formed from the ventral non-metameric part of the mesoderm of the cranial end of the embryo. This group of muscles (visceral muscles) includes the masticatory muscles, some muscles of the neck, which form through transformation of the first visceral arch; the muscles of facial expression (including the platysma) and some other muscles that form from the second visceral arch. The sternocleidomastoid and trapezius muscles develop from the brachial arch musculature. This group also includes some muscles of the perineum, for example the levator ani muscle. Some muscles develop from myotomes of cranial somites. These include the muscles that move the eyeball.

Some muscles develop from mesenchymal rudiments of the limbs, and their proximal ends later move onto the body. This group of muscles includes the pectoralis major, pectoralis minor, latissimus dorsi and psoas major muscles. There is also a group of muscles, which move from the body onto a limb. These include the trapezius, rhomboid, sternocleidomastoid, serratus anterior, omohyoid and levator scapuli muscles. The muscles of this group develop from the ventral sections of myotomes and from the brachial musculature. Their distal ends move from the body onto the bones of the skull or extremities. There are also muscles, which develop from mesenchyme of the limbs and remain on the extremities.

Questions for revision and examination

1. Name the parts of a muscle.
2. Which anatomic formations make up the auxiliary apparatus of muscles?
3. How are muscles divided according to their shape and structure?
4. Name the different types of levers and give a functional characteristic of each.
5. What does the force exerted by a muscle depend on? What are the anatomic and physiological cross sections and what is their practical significance?
6. What types of work can be performed by muscles? Characterize each type.

MUSCLES AND FASCIAE OF THE BACK

The upper border of the back considered is to be the external occipital protuberance and the upper nuchal line of the occipital bone. Its lower border is the iliac crest and the sacrum. The lateral borders are drawn along the posterior axillary lines (table 8).

The back is divided into vertebral, lumbar, sacral, scapular and infrascapular regions. For convenience, muscles of the posterior region of the neck are described together with the muscles of the back.

The muscles of the back are paired; they are situated in layers and can be divided into superficial and deep.

SUPERFICIAL MUSCLES OF THE BACK

The superficial muscles of the back are attached to the bones of the shoulder girdle and the humerus. They are situated in two layers (Fig. 91). The first layer includes the trapezius and the latissimus dorsi muscles. The second layer consists of the major and minor rhomboid muscles, the levator scapulae, the serratus posterior superior and inferior muscles.

The trapezius muscle (m. trapézius) is flat and triangular. It begins with a short tendon on the external occipital protuberance, the medial part of the upper nuchal line, the nuchal ligament and the spinous processes of the C7 vertebra and all thoracic vertebrae. Its upper fascicles pass downwards lateraly, the middle fascicles pass almost horizontally and the lower bunches pass upwards and to the lateral. The trapezius muscle is inserted into the lateral third of the clavicle, the acromion and the scapular spine.

F u n c t i o n: by simultaneous contraction of all its parts, the trapezius moves the scapula to the vertebral column. The upper fascicles of the muscle bring the scapula up. During simultaneous contraction of its upper and lower fascicles, the trapezius moves the lateral scapular angle upwards medially, while its lower angle moves forwards laterally. If the scapulae are fixed, contraction of both sides of the trapezius causes the cervical part of the spine to straighten. Contraction of only one side turns the face toward the opposite side.

I n n e r v a t i o n: the accessory nerve, cervical plexus.

B l o o d s u p p l y: transverse artery of the neck, suprascapular artery, occipital artery, posterior intercostal arteries.

The latissimus dorsi muscle (m. latíssimus dórsi) is flat and triangular. It begins from the spinous processes of the lower six thoracic and all lumbar vertebrae, the iliac crest, the median sacral crest and the 3–4 lower ribs. Fascicles of the muscle are directed upwards and laterally. Near the posterior margin of the axillary fossa the muscle continues into a flat thick tendon, which attaches to the crest of the lesser tubercle of humerus.
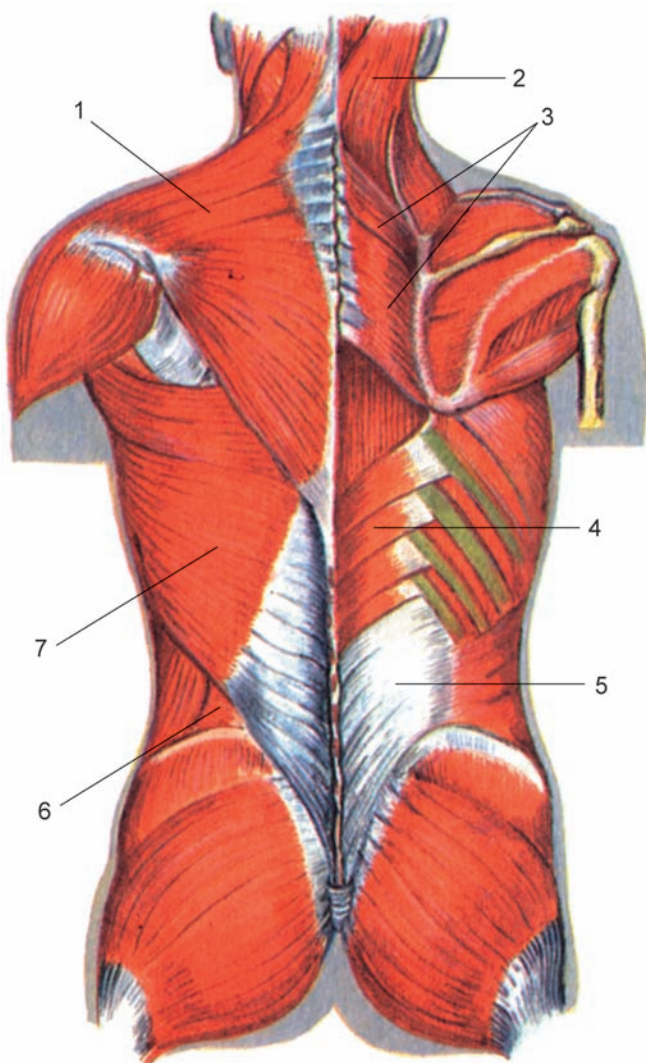
Fig. 91. Superficial muscles of back**.**
1 — trapezius; 2 — splenius capitis; 3 — rhomboid muscles major and minor; 4 — serratus posterior;
5 — thoracolumbar fascia; 6 — lumbar triangle; 7 — latissimus dorsi.

F u n c t i o n: The latissimus dorsi muscle causes adduction of the arm to the body and lowering of a raised arm, and pronation and extension in the shoulder. When the arms are fixed, this muscle pulls the body towards them (for example, when doing pull ups).

I n n e r v a t i o n: thoracodorsal nerve.

B l o o d   s u p p l y: thoracodorsal artery, posterior circumflex humeral artery, posterior intercostal arteries.

The levator scapulae muscle (m. levátor scápulae) begins with tendon fascicles from the transverse processes of 3–4 upper cervical vertebrae, passes downwards and attaches the upper part of the medial margin of the scapula. In its upper third it is covered by the sternocleidomastoid muscle, and in its lower third — by the trapezius.

F u n c t i o n: This muscle lifts the scapula, bringing it closer to the spine. If the scapula is fixed, the muscle bends the cervical spine toward itself.

I n n e r v a t i o n: dorsal scapular nerve.

B l o o d   s u p p l y: cervicalis ascendens artery, transverse cervical artery.

The rhomboid major and minor muscles (mm. rhomboidei minor et major) are situated beneath the trapezius muscle.

The rhomboid minor muscle begins from the spinous processes of the C7 and T1 vertebrae. The muscle stretches downwards and laterally, and attaches to the medial margin of scapula, above the scapular spine.

The rhomboid major muscle begins from the spinal processes of T2-T5 vertebrae and ends at the medial margin of the scapula, below the scapular spine. The rhomboid major and minor muscles are often accreted with each other.

F u n c t i o n: The rhomboid muscles move the scapula towards the vertebral column, raising it up.

I n n e r v a t i o n: dorsal scapular nerve.

B l o o d   s u p p l y: transverse cervical artery, suprascapular artery.

The serratus posterior superior muscle (m. serrátus postérior superior) is thin and flat. It is situated beneath the rhomboid muscles. It begins with a flat tendon from the spinous processes of the C6, C7, T1 and T2 vertebrae. The muscle stretches downwards laterally, and attaches to the back surfaces of ribs 1–5 lateral of their angles.

F u n c t i o n: This muscle lifts the ribs.

I n n e r v a t i o n: intercostal nerves.

B l o o d   s u p p l y: posterior intercostal arteries, deep cervical artery.

The serratus posterior inferior muscle (m. serrátus postérior inferior) is flat and thin; it is situated to the front of the latissimus dorsi muscle. It begins on the spinous processes of the T11, T12, L1 and L2 vertebrae and attaches to the lower 4 ribs.

F u n c t i o n: It lowers the ribs.

I n n e r v a t i o n: intercostal nerves.

B l o o d   s u p p l y: posterior intercostal arteries.

DEEP MUSCLES OF THE BACK

The deep muscles of the back are situated in three layers. The superficial layer consists of the splenius capitis muscle, the splenius cervicis muscle and the erector spinae muscle (Fig. 92, 93). The middle layer of the deep muscles includes the tranversospinales muscles, and the profound layer is formed by the interspinales and suboccipital muscles.
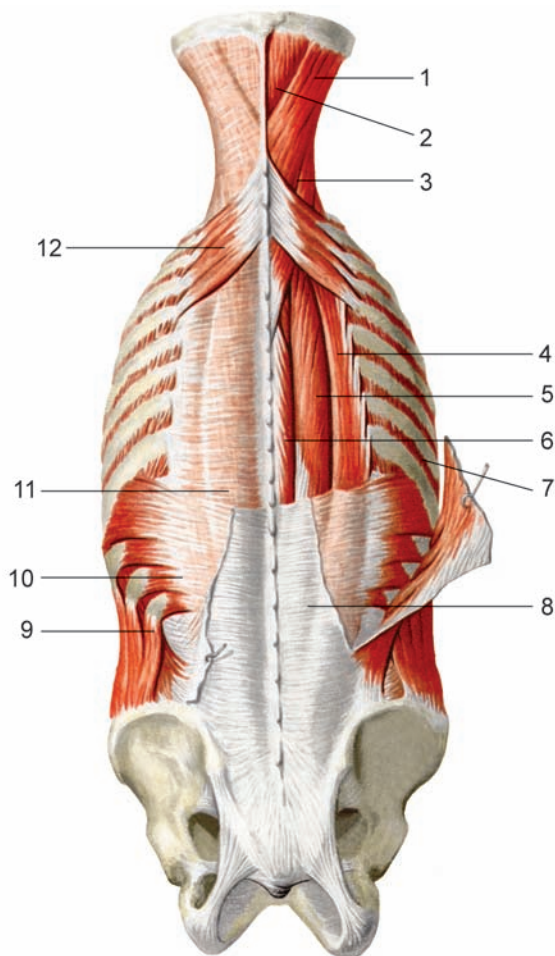

Fig. 92. Deep muscles of back. To the left back from the m. erector spinae superior and inferior serrate muscles are kept; and from the right they're removed**.**

1 — splenius capitis; 2 — semispinalis capitis; 3 — splenius cervicis; 4 — iliocostalis thoracis; 5 — longissimus; 6 — spinalis; 7 — external intercostal; 8 — thoracolumbar fascia (removed); 9 — obliqus externus abdominis; 10 — serratus posterior inferior; 11 — erector spinae; 12 — serratus posterior superior.
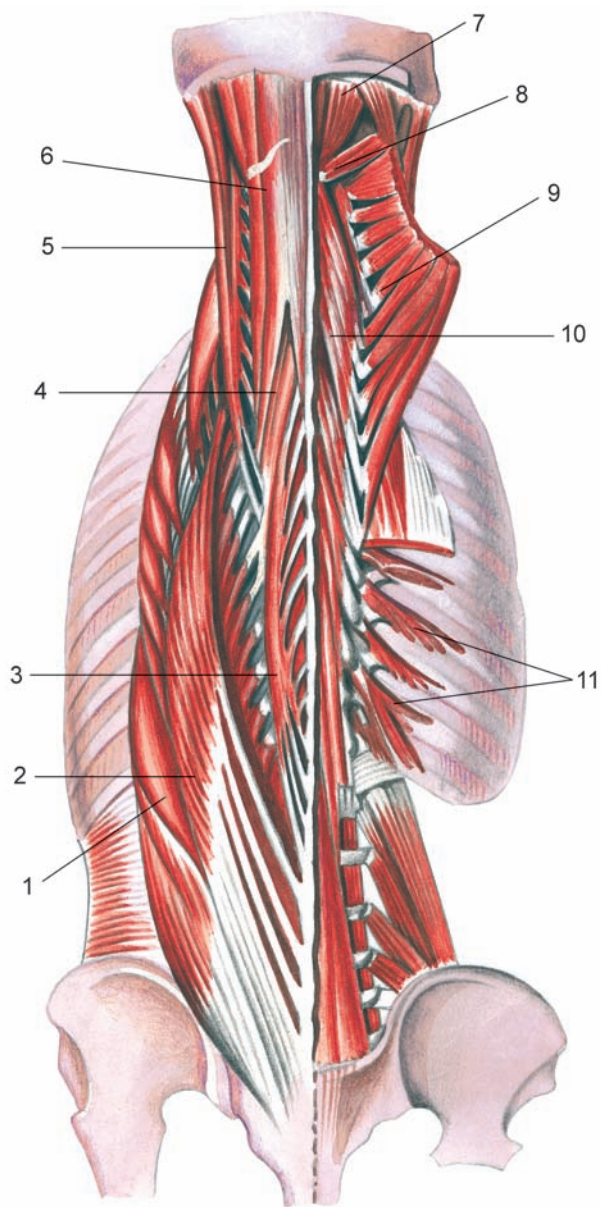
Fig. 93. Deep muscles of back; from the right erector spinae is revealed; from the left — spinotransversalis.

1 — iliocostalis; 2 — longissimus; 3 — spinalis; 4 — semispinalis cervicis; 5 — longissimus capitis and cervicis; 6 — semispinalis capitis; 7 — rectus capitis posterior major; 8 — obliqus capitis inferior; 9 — semispinalis capitis; 10 — semispinalis cervicis; 11 — levatores costarum.

The splenius capitis muscle (m. splénius cáapitis) is situated in front of the upper parts of the sternocleidomastoid and trapezius muscles. It begins on the spinous processes of the C7 and the upper 3–4 thoracic vertebrae. It stretches laterally upwards and attaches to the mastoid process of the temporal bone.

F u n c t i o n: One-sided contraction turns the head to the corresponding side; contraction on both sides straightens the cervical part of the vertebral column.

I n n e r v a t i o n: posterior branches of the cervical spinal nerves.

B l o o d s u p p l y: deep cervical artery, occipital artery.

The splenius cervicis muscle (m. splénius cérvicis) is situated to the front of the trapezius muscle. It begins on the spinous processes of the T3 andT4 vertebrae and attaches to the posterior tubercles of the transverse processes of 2–3 upper cervical vertebrae.

F u n c t i o n: During one-sided contraction the cervical part of the spine turns to the corresponding side; contraction of the muscle on both sides causes the cervical part of the spine to straighten.

I n n e r v a t i o n: posterior branches of the cervical spinal nerves.

B l o o d s u p p l y: deep cervical artery, occipital artery.

The erector spinae muscle (m. eréctor spínae) is situated along the entire length of the spine. It is situated to the front of the trapezius, rhomboid, posterior occipital and the latissimus dorsi muscles. It is covered in the back by the superficial sheet of the thoracolumbar fascia. The muscle begins on the dorsal surface of the sacrum, spinous processes of all lumbar and 2 lower thoracic vertebrae, the iliac crest (its dorsal part), the thoracolumbar fascia, and the sacrospinous and sacrotuberal ligaments. The erector spinae muscle is divided into three parts: lateral (the iliocostalis muscle), intermediate (the longissimus muscle), and medial (the spinalis muscle). Each of these muscles is subdivided into three parts.

The iliocostalis muscle (m. iliocostális) is the most lateral part of the erector spinae muscle. It is divided into the iliocostalis lumborum, thoracis and cervicis muscles, depending on what region they are in. The iliocostalis lumborum muscle originates on the iliac crest and the superficial lamina of the thoracolumbar fascia, and is inserted into the angles of lower 6 ribs. The iliocostalis thoracis muscle originates on the 6 lower ribs, medially of the insertion of the iliocostalis lumborum muscle. It attaches to the angles of the upper 6 ribs and the posterior surface of the transverse process of C7 vertebra. The iliocostalis cervicis muscle originates on the angles of ribs 3–4, medially of the insertion of the iliocostal thoracis muscle. It inserts into the posterior tubercles of transverse processes of C3 and C4 vertebrae.

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F u n c t i o n: This muscle straightens the vertebral column by contracting on both sides. During one-sided contraction it bends the vertebral column to the corresponding side. It also lowers the ribs.

The longissimus muscle (m. longíssimus) is situated more medially from the iliocostalis muscle. It is divided into three parts: the longissimus thoracis, longissimus cervicis and longissimus dorsi.

The longissimus thoracis muscle originates on the dorsal surface of the sacrum and the transverse processes of the lumbar and lower thoracic vertebrae. It inserts on the dorsal surface of the lower 9 ribs, between their tubercles and angles. The longissimus cervicis muscle begins on the apexes of transverse processes of 5 upper thoracic vertebrae. It attaches on the posterior tubercles of transverse processes of C2–C6 vertebrae. The longissimus capitis muscle originates on the transverse processes of the T1–T3 and C3–C7 vertebrae. It is inserted into the back of the mastoid process of the temporal bone.

F u n c t i o n: During contraction on both sides the longissimus thoracis and cervicis muscles straighten the vertebral column; during one-sided contraction they promote the inclination of the spine to the corresponding side. The longissimus cervicis muscle bends the head backwards.

The spinalis muscle (m. spinális) is situated medially of the longissimus muscle, adjoining the spinous processes of thoracic and cervical vertebrae. It is divided into the spinalis thoracis, spinalis cervicis and spinalis capitis muscles. The spinalis thoracis muscle originates from the spinous processes of L1–L2 and T11–T12 vertebrae. It inserts into the spinous processes of the T1–T8 vertebrae. The spinalis cervicis muscle stretches between the spinous processes of T1 and T2 vertebrae to the spinous process of the C2 vertebra (sometimes also C3 andC4). The spinalis capitis muscle originates from the spinous processes of the upper thoracic and the lower cervical vertebrae, and attaches to the external occipital protuberance (this muscle is often absent).

F u n c t i o n: The spinal muscles straighten the vertebral column.

The function of the entire erector spinae muscle consists of straightening the vertebral column and head. The muscle is antagonist of the anterior muscles of the body. During its one-sided contraction the vertebral column bends to the corresponding side. The muscle plays an important role in performing yielding work during the bending of the body forward, preventing it from falling.

I n n e r v a t i o n: posterior branches of the cervical, thoracic and lumbar spinal nerves.

B l o o d s u p p l y: deep cervical artery, posterior intercostal arteries, lumbar arteries.

The transversospinales muscle (m. transversospináles) consists of many muscle fibers of different lengths, obliquely oriented and situated in layers. The muscle consists of different parts, which differ in length of muscle fibers. They are called the semispinal, multifidus and rotator muscles.

The semispinalis muscle (m. semispinális) consists of long muscle fascicles, which originate from the transverse processes of vertebrae, stretch upward and medially, span 4–6 vertebrae and attach to the spinous processes. The semispinalis muscle has a thorax, neck and head sections. The semispinalis thoracis and cervicis muscles originate from the transverse processes of all thoracic vertebrae and are inserted on the spinous processes of T1–T6 and C2–C7 vertebrae.

The semispinalis capitis muscle of the head originates on the transverse processes of T1–T4 and C4–C7 vertebrae, and inserts in the occipital bone (between the superior and inferior nuchal lines).

F u n c t i o n: Contraction of semispinales muscles on both sides causes the thoracic and cervical parts of the spine and the head to straighten. During one-sided contraction they turn the neck and the head toward the opposite side.

I n n e r v a t i o n: posterior branches of cervical and thoracic spinal nerves.

B l o o d s u p p l y: deep cervical artery, posterior intercostal arteries.

The multifidus muscles (mm. multífídi) originate from the dorsal surface of the sacrum and on transverse processes of all vertebrae up to C2. They stretch upward and medially, span 2–4 vertebrae and insert into spinous processes.

F u n c t i o n: These muscles turn the vertebral column about the vertical axis, toward the opposite side.

I n n e r v a t i o n: posterior branches of the spinal nerves.

B l o o d s u p p l y: deep cervical artery, posterior intercostal and lumbar arteries.

The rotatores muscles (mm. rotátores) form the deepest layer of muscles of the back. They are best expressed in the thoracic section of the spine. These muscles originate from transverse processes and stretch upward and medially. They insert into the base of the next or second to next vertebra above.

F u n c t i o n: They turn the vertebral column about the vertical axis to the opposite side.

I n n e r v a t i o n: posterior branches of the spinal nerves.

B l o o d s u p p l y: deep cervical artery, posterior intercostal and lumbar arteries.

The intertransversarii muscles (mm. inertransversárii) are short muscle fascicles, which stretch between transverse processes of adjacent vertebrae. They are not well expressed in the thoracic part of the spine.

F u n c t i o n: They bend the appropriate parts of the vertebral column to the corresponding side.

I n n e r v a t i o n: posterior branches of spinal nerves.

B l o o d   s u p p l y: deep cervical artery, posterior intercostal and lumbar arteries.

The interspinales muscles (mm. interspináles) stretch between the spinuos processes of neighboring vertebrae. In the thoracic part of the spine these muscles are often absent or poorly expressed.

F u n c t i o n: They participate in straightening the vertebral column.

I n n e r v a t i o n: posterior branches of spinal nerves.

B l o o d   s u p p l y: deep cervical artery, posterior intercostal and lumbar arteries.

The suboccipital muscles (mm. suboccipitáles). There are four muscles included in this group. They are situated in the occipital region between the skull and the C1 and C2 vertebrae, to the front of the semispinalis and splenius capitis muscles (Fig. 94). These are the paired rectus capitis posterior major, rectus capitis posterior minor muscles, obliquus capitis superior muscle, obliquus capitis inferior muscles.

The rectus capitis posterior major (m. réctus cápitis postérior májor) originates on the spinous process of the C2 vertebra. It stretches upwards and to the laterally and inserts on the occipital bone, beneath the lower nuchal line.

F u n c t i o n: During two-sided contraction the muscle bends the head backwards; and during one-sided contraction it moves the head to its side.

I n n e r v a t i o n: suboccipital nerve.

B l o o d   s u p p l y: deep cervical artery.

The rectus capitis posterior minor (m. réctus cápitis postérior minor) originates from the posterior tubercle of the atlas, passes upwards and inserts into the occipital bone below the nuchal line, deeper and more medially than the rectus capitis posterior major muscle.

F u n c t i o n: Straightening the head.

I n n e r v a t i o n: suboccipital nerve.

B l o o d   s u p p l y: deep cervical artery.

The obliquus capitis superior muscle (m. obliquus cápitis supérior) stretches from the transverse process of the atlas medially and upwards, and inserts into the occipital bone above the inferior nuchal line.

F u n c t i o n: During two-sided contraction the head extends backwards, and during one-sided contraction the head turns to the corresponding side.
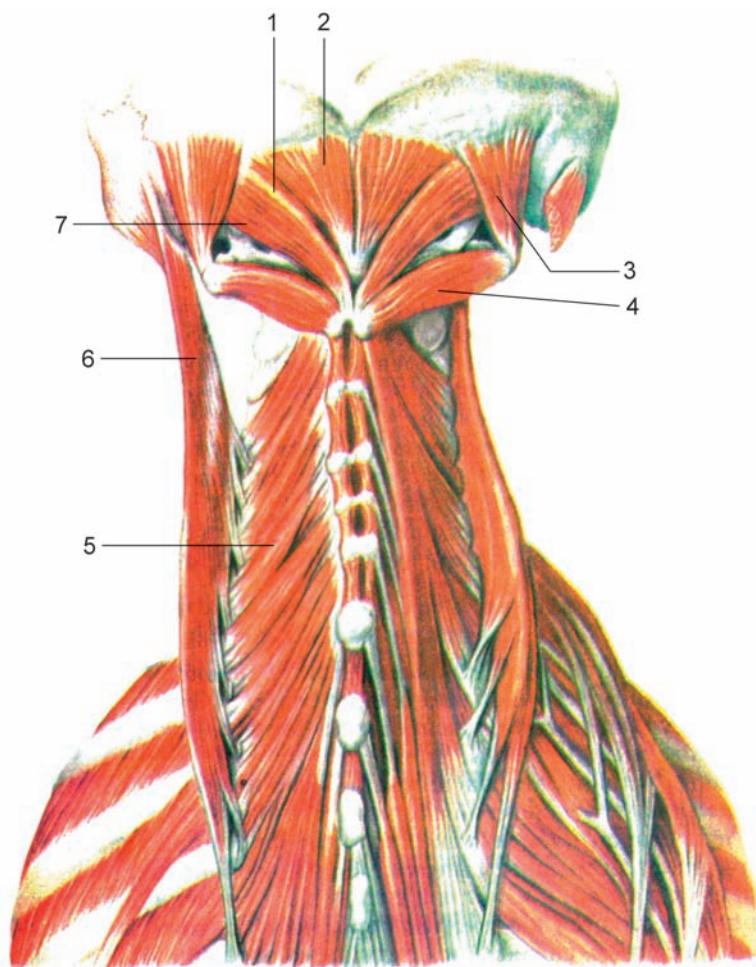
Fig. 94. Suboccipital and deep muscles of posterior aspect of neck.

1 — external occipital protuberance; 2 — rectus posterior capitis minor; 3 — posterior tubercle of atlas; 4 —   oblique capitis inferior; 5 — spinous process of axis; 6 — obliquus capitis superior; 7 — rectus capitis posterior major.

I n n e r v a t i o n: suboccipital nerve.

B l o o d   s u p p l y: deep cervical artery.

The obliquus capitis inferior muscle (m. oblíquus cápitis inféri-or) begins on the spinous process of the C2 vertebra and passes laterally and upwards to the transverse process of the atlas.

F u n c t i o n: The head is turned to the opposite side.

I n n e r v a t i o n: suboccipital nerve.

B l o o d   s u p p l y: deep cervical artery.

Muscles of the back and suboccipital region are demonstrated in the table 8.

FASCIAE OF THE BACK

The superficial fascia of the back, which covers the trapezius and latissimus dorsi muscles, is not markedly developed. **The thoracolumbar fascia (fáscia thoracolumbális)**, which covers the deep muscles of the back, is developed quite well, especially in the lumbar region, where it is divided into superficial and deep laminae. Its superficial lamina is attached medially to the apexes of spinous processes of all thoracic and lumbar vertebrae, to the middle sacral crest and, laterally, to the angles of ribs. The d e e p   l a m i n a of this fascia medially attaches to the transverse processes of lumbar vertebrae, at the top — to the twelfth rib, and at the bottom — to the iliac crest. The two plates fuse together near the lateral edge of the erector muscle of the spine, forming a fascial sheath around this muscle.

On the dorsal region of the neck, between its muscles, are the laminae of **the nuchal fascia (fáscia núchae)**.

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE BACK

The external occipital protuberance, the spinal processes of C2, C7 and all thoracic and lumbar vertebrae, and the middle sacral crest can all be palpated in a living person. The cervical and lumbar lordoses and the thoracic and sacral kyphoses are also easily detectable. Normally, on either side of the spine it is possible to palpate the lower and medial angles of the scapula, the scapular spine and the ribs. The erector muscles of spine can be seen along the sides the middle line. They are fused with the superficial fascia by fascicles of connective tissue. The skin of this region contains a lot of sweat and sebaceous glands. The subcutaneous fat is well developed, especially in women. It contains the posterior and lateral branches of intercostal and lumbar blood vessels, as well as nerves and their endings.

To the front of the fascial sheaths of the trapezius and latissimus dorsi muscles, which partially cover the scapula, there is a loose fatty tissue space that separates these muscles from the splenius muscles of the head and neck, the levator scapula, rhomboid and serratus muscles.

Table 8. Muscles of the back and suboccipital region.

Muscle	Origin	Insertion	Action	Innervation
Superficial muscles of the back				
Trapezius	External occipital protuberance, superior nuchal line, nuchal ligament and the spinous processes of the C7 and all thoracic vertebrae	Acromial end of clavicle, acromion and spine of scapula	Brings the scapula to the vertebral column; rotates it about the sagittal axis; bilateral contraction bend the head back, extending the cervical spine	Accessory nerve and branches of cervical plexus
Latissimus dorsi	Spinous processes of six lower thoracic and all lumbar vertebrae, external lip of iliac crest, dorsal surface of sacrum and ribs 9-12	Crest of the lesser tubercle of humerus	Adduction, pronation and retraction of the arm. When the arms are fixed (during pull ups) it pulls the body towards them	Thoracodorsal nerve
Rhomboid major	Spinous processes of T1-T5 vertebrae	Medial margin of scapula, below the spine	Brings scapula upward and to the vertebral column; pulls it against thoracic wall	Dorsal scapular nerve
Rhomboid minor	Spinous processes of C6-C7 vertebrae	Medial margin of scapula, above the spine	Same as above	Same as above
Levator scapulae	Transverse processes of C1-C4 vertebrae	Superior angle of scapula	Raises the superior angle of scapula and pulls it medially	Same as above
Serratus posterior superior	Spinous processes of C6, C7, T1 and T2 vertebrae	Ribs 2-5 (to the outside of their angles)	Raises ribs 2-5, participating in inspiration	Intercostal nerves
Serratus posterior inferior	Spinous processes of T11-T12 and L1-L2 vertebrae	Inferior margins of ribs 9-12	Lowers ribs 9-12, participating in expiration	Same as above

	Deep muscles of the back		
Splenius capitis	Lower part of nuchal ligament, spinous processes of C7 and T1-T4 vertebrae	Superior nuchal line and mastoid process	Turns and bends the head to same side	Posterior branches of spinal nerves
Splenius cervicis	Spinous processes of T3-T4 vertebrae	Transverse processes of 2-3 upper cervical vertebrae	Turns cervical spine to the same side; bilateral contraction extends the neck	Same as above
Erector spinae muscle	Dorsal surface of sacrum, external lip of iliac crest, spinous processes of lumbar and lower thoracic vertebrae and thoracolumbar fascia		Holds the trunk in a vertical (erect) position; extends the vertebral column	Same as above
Iliocostalis		Angles of ribs and transverse processes of C4-C7 vertebrae		
Longissimus		Transverse processes of lumbar, thoracic and cervical vertebrae, angles of ribs 2-12, and mastoid process		
Spinalis		Spinous processes of thoracic and cervical vertebrae		
Tranverso-spinales Semispinalis Multifidus Rotatores	Transverse processes of vertebrae	Spinous processes of above-lying vertebrae	Extension, rotation and bending of the vertebral column	Posterior branches of spinal nerves

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Interspinal	Spinous processes of vertebrae	Spinous processes of above-lying vertebrae	Extension of the spine	Same as above
Intertrans-versarii	Transverse processes of vertebrae	Transverse processes of above-lying vertebrae	Bend the spine to same side	Same as above
Muscles of the suboccipital region				
Rectus capitis posterior major	Spinous process of C2 (axis) vertebra	Occipital bone, below the inferior nuchal line	Rotation and bending of head to the sides	Suboccipital nerve
Rectus capitis posterior minor	Posterior tubercle of atlas	Same as above	Extension of neck and bending of head to the sides	Same as above
Obliquus capitis superior	Transverse process of atlas	Occipital bone, above the inferior nuchal line	Bending of the head to the back and the sides	Same as above
Obliquus capitis inferior	Spinous process of axis	Transverse process of atlas	Turning of the head to same side	Same as above

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The upper border of the lumbar region can be palpated at the twelfth rib and the free ends of ribs 11 and 12. The lower border of the lumbar region passes along the iliac crest. The outer (lateral) border corresponds to the prolongation of the middle axillary line. Above the highest point of the iliac crest there is a palpable fossa, which corresponds to the lu m b a r   t r i a n g l e. This is the weakest place of the lumbar region and often becomes an outlet of lumbar hernias. The borders of this triangle are: the iliac crest (at the bottom); the lateral edge of the latissimus dorsi muscle aponeurosis (medial); and the dorsal edge of the external abdominal oblique muscle (lateral). The floor of this triangle is formed by the internal abdominal oblique muscle.

Above the horizontal line that connects the iliac crests it is possible to palpate the spinous process of the L4 vertebra, which serves as orientation for defining the level of the other lumbar vertebrae.

The superficial fascia, which covers the trapezius muscle, is not well-developed. In the lumbar region, beneath this fascia, there is a lumbogluteal fatty tissue space, which covers the lower sections of the latissimus dorsi muscle.

The superficial and deep laminae of the thoracolumbar fascia are well developed in the lumbar region. The deep lamina is situated between the quadratus lumborum muscle and the erector muscle of the spine. The thick upper edge of the deep lamina, which is stretched between the transverse process of the L1 vertebra and the twelfth rib, is called the lumbocostal ligament. The tendon origin (aponeurosis) of the latissimus dorsi muscle is accreted with the superficial lamina of the thoracolumbar fascia.

In the occipital region there is the o c c i p i t a l   t r i a n g l e, which is bordered by the major posterior rectus and the two oblique muscles. At the floor of this triangle, beneath the fascia and the fatty tissue is the posterior arch of the atlas. Between the arch and the occipital bone there is a thick posterior atlanto-occipital ligament.

Questions for revision and examination

1. What groups are the muscles of the back divided into according to their origin and depth?
2. What parts is the erector muscle of the spine divided into?
3. Which muscles of the back lift the ribs, and which muscles lower them?
4. What actions does the suboccipital group of muscles perform?
5. Name the fasciae of the back and describe their anatomic and functional characteristics.

MUSCLES AND FASCIAE OF THE THORAX

Muscles of the thorax are situated within the thorax region in several layers. Muscles of the superficial layer develop in association with the
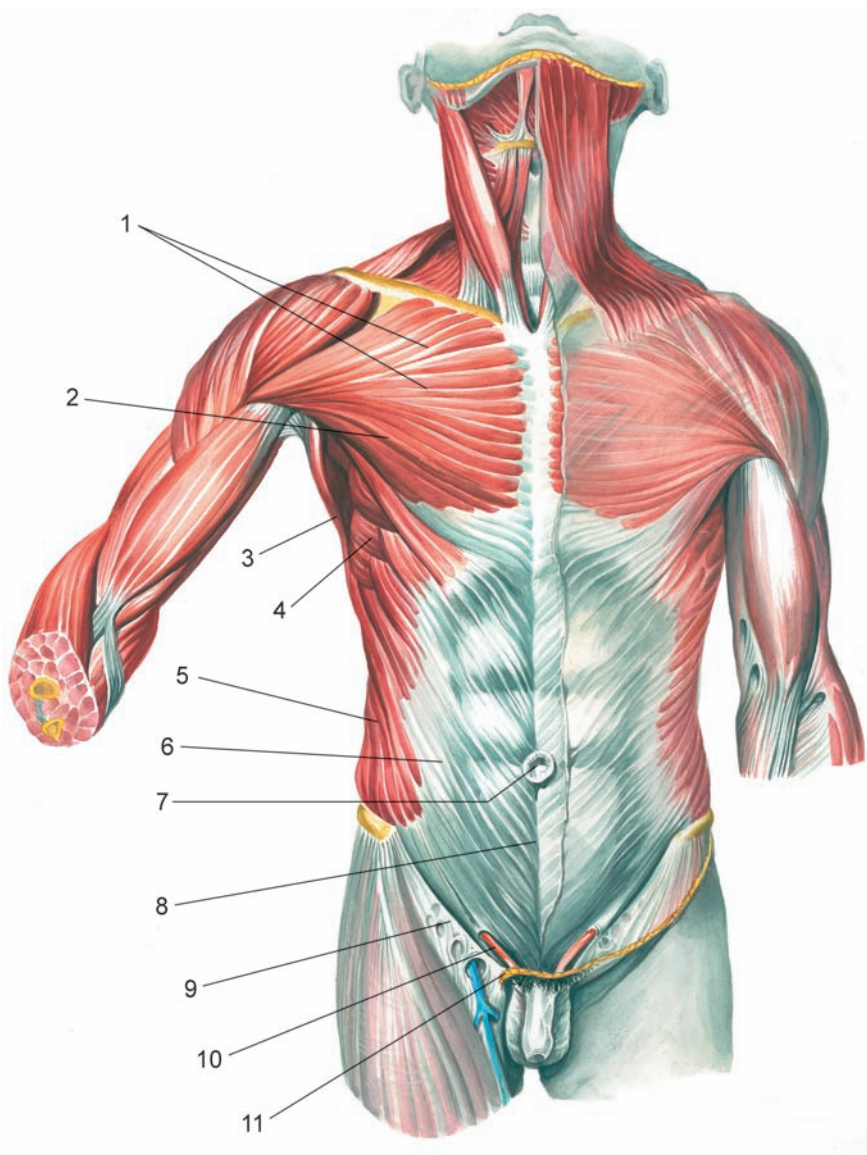
Fig. 95. Superficial muscles of thorax and abdomen.

1 — pectoralis major; 2 — axillary cavity; 3 — latissimus dorsi; 4 — serratus anterior; 5 — external oblique; 6 — aponeurosis of external oblique (of abdomen); 7 — anulus umbilicalis; 8 — linea alba (of abdomen); 9 — inguinal ligament; 10 — superficial inguinal ring; 11 — spermatic cord.
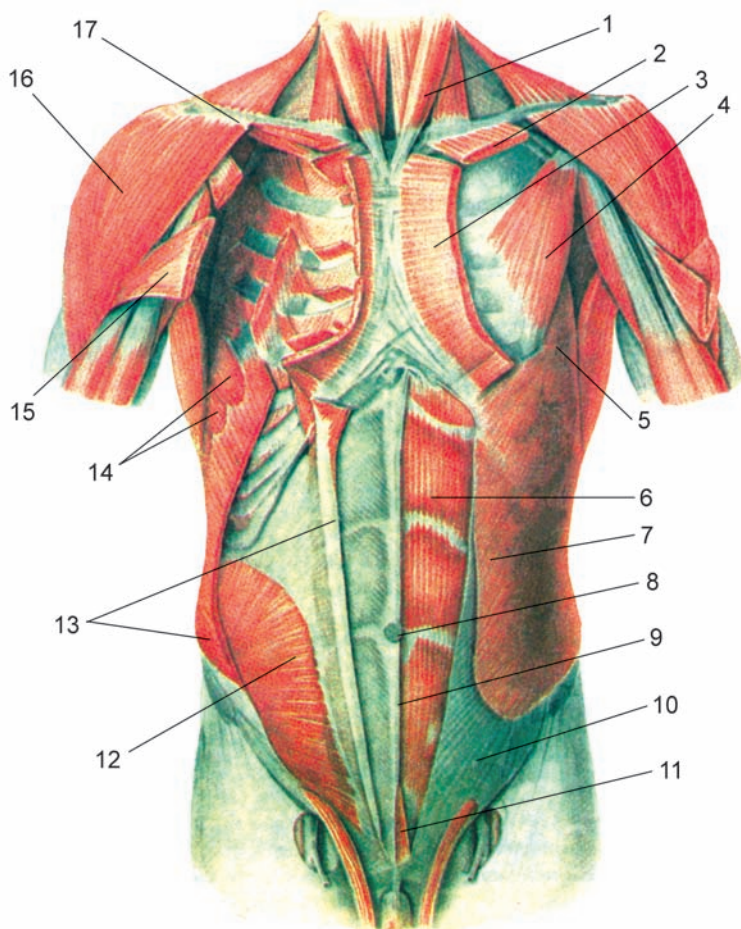
Fig. 96. Muscles of thorax and abdomen.

Pectoralis major muscle (on both sides) and external oblique muscle of abdomen(left) are removed. On the right side of a picture an anterior layer of rectus sheath is also removed.

1 — sternocleidomastoid; 2 — trapezium; 3 — pectoralis major (removed); 4 — pectoralis minor; 5 — serratus anterior; 6 — rectus abdominis; 7 — external oblique (of abdomen); 8 — umbilical ring; 9 — linea alba; 10 — aponeurosis of external oblique; 11 — pyramidalis; 12 — internal oblique (of abdomen); 13 — external oblique (cut off and partially removed); 14 — serratus anterior; 15 — pectoralis major; 16 — deltoid; 17 — subclavius.

upper extremities. This group includes the pectoralis major and pectoralis minor muscles, subclavius and serratus anterior muscles (Fig. 95 and 96). Beneath the superficial layer are the proper muscles of the thorax. They develop from the anterior portions of myotome. Both their origin and insertion are in the thorax.

The diaphragm can be discussed together with the muscles of the chest because of their close anatomical and functional association.

The pectoralis major muscle (m. pectorális május) occupies a large area of the front thoracic wall. It has three parts, named according to their origin. The sternocostal part originates from the anterior surface of the sternum and cartilages of the upper 6 ribs. The clavicular part originates from the medial half of the clavicle; and the abdominal part—from the front of the rectus abdominis muscle sheath. Fascicles of the pectoralis major muscle converge laterally and insert into the crest of the greater tubercle of humerus.

F u n c t i o n: It lowers the raised arm, causes adduction and pronation. When the upper extremity is fixed (in a raised position), it raises the ribs and sternum, expanding the thoracic cavity and thus promoting inspiration.

I n n e r v a t i o n: medial and lateral pectoral nerves.

B l o o d s u p p l y: thoracoacromial artery, posterior intercostal arteries, anterior intercostal branches of the internal thoracic artery, lateral thoracic artery.

The pectoralis minor muscle (m. pectorális mínor) is flat, narrow, triangularly shaped. It is situated beneath the pectoralis major muscle. Its origin is on the anterior ends of ribs 3–5. It stretches laterally and upwards and is inserted into the coracoid process of the scapula.

F u n c t i o n: This muscle bends the scapula forward; when the shoulder girdle is fixed, it lifts the ribs.

I n n e r v a t i o n: medial and lateral pectoral nerves.

B l o o d s u p p l y: thoracoacromial artery, anterior intercostal branches.

The subclavius muscle (m. subclávius) is long and thin, and is situated between the clavicle and the first rib. It stretches laterally and attaches to the inferior surface of the acromial end of the clavicle.

F u n c t i o n: Moves the clavicle downwards and towards the front.

I n n e r v a t i o n: subclavian nerve.

B l o o d s u p p l y: transverse cervical artery, throcoacromial artery.

The serratus anterior (m. serrátus antérior) is a flat muscle, situated on the anterolateral surface of the thorax. It originates from the upper 8–9 ribs by separate muscle fascicles, and inserts on the medial margin

and inferior angle of the scapula. Its upper and lower fascicles are oriented horizontally, the lower fascicles slanting upward and to the back.

F u n c t i o n: Shifts the scapula to the front and the side; lower fascicles turn its lateral angle medial and upwards. When the scapula is fixed this muscle lifts the ribs, thus expanding the thorax.

I n n e r v a t i o n: long thoracic nerve.

B l o o d s u p p l y: thoracodorsal artery, lateral thoracic artery, posterior intercostal arteries.

PROPER MUSCLES OF THE THORAX

The external intercostal muscles (mm. intercostáles extérni) are located in the intercostal spaces. They originate from lower edges of ribs, outside the costal grooves. Their fascicles stretch down and forward and insert into the upper border of the next rib.

F u n c t i o n: These muscles lift the ribs; in the back they strengthen the costovertebral joints.

I n n e r v a t i o n: intercostal nerves.

B l o o d s u p p l y: posterior intercostal arteries, musculophrenic artery, internal thoracic artery.

The internal intercostal muscles (mm. intercostáles intérni) are situated behind the external intercostals. They originate from the upper borders of ribs and insert into the lower borders of above-lying ribs. Their muscle fascicles take up the space from the sternum and costal cartilages of ribs 11 and 12 to the angles of ribs in the back. They are oriented obliquely, almost perpendicularly to the fascicles of the external intercostal muscles.

F u n c t i o n: lowering the ribs.

I n n e r v a t i o n: intercostal nerves.

B l o o d s u p p l y: posterior intercostal arteries, internal thoracic artery, musculophrenic artery.

The transversus thoracis muscle (m. transvérsus thóracis) lies on the internal surface of the anterior thoracic wall. It originates from the xiphoid process and lower half of the sternum. Its muscle fascicles diverge like a fan and insert into cartilages of ribs 2–11. The upper fascicles are oriented somewhat vertically, while the middle and lower fascicles are directed obliquely and horizontally.

F u n c t i o n: The muscle pulls down the costal cartilages and lowers the ribs.

I n n e r v a t i o n: intercostal nerves.

B l o o d s u p p l y: internal thoracic artery.

Table 9. Muscles of the thorax.

Muscle	Origin	Insertion	Action	Innervation
Superficial muscles of the thorax				
Pectoralis major	Medial half of clavicle, manubrium and body of sternum, cartilages of ribs 2-7 and sheath of the rectus abdominis muscle	Crest of greater tubercle	Adduction of humerus; raising of the ribs (participates in inspiration)	Medial and lateral pectoral nerves
Pectoralis minor	Ribs 3-5	Coracoid process of scapula	Brings the scapula forward and down; when pelvic girdle is fixed it raises the ribs	Anterior branches of pectoral nerves
Subclavius	Cartilage of rib 1	Acromial end of clavicle	Pulls clavicle medially and downward	Subclavian nerve
Serratus anterior	Ribs 1-9	Medial margin and inferior angle of scapula	Pulls scapula laterally and downward	Long thoracic nerve
Deep muscles of the thorax				
External intercostal	Inferior edges of ribs	Superior edges of below-lying ribs	Raises ribs	Intercostal nerves
Internal intercostals	Superior edges of ribs	Inferior edges of above-lying ribs	Lowers ribs	Same as above
Subcostales	Next to angles of ribs 10-12	Inner surfaces of above-lying ribs	Same as above	Same as above
Transversus thoracis	Xiphoid process and border of the inferior part of sternum	Ribs 2-6	Same as above	Same as above
Levatores costarum	Transverse processes of C7 and T1-T11 vertebrae	Angles of closest ribs	Raises ribs	Same as above

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Muscles of the thorax are demonstrated in the table 9.

The subcostales muscles (mm. subcostales) are situated in the lower back portion of the internal surface of the thorax. They originate from the angles of ribs 10–12 and stretch upward and laterally. They span one or two ribs and inset into the internal surface of the above-lying rib.

F u n c t i o n: These muscles raise the ribs.

I n n e r v a t i o n: intercostal nerves.

B l o o d   s u p p l y: posterior intercostal arteries.

The diaphragm (diaphrágma, m. phrénicus) is a thin, wide musculotendinous septum, which separates the thoracic and abdominal cavities. The diaphragm is the main breathing muscle. It develops from cervical myotomes. Its convex side is turned upward, into the thoracic cavity, and its concave side looks into the abdominal cavity (Fig. 97).

Its muscle fascicles originate from the periphery and converging towards the center they form the central tendon of diaphragm (centrum tendineum). According to the origin, the diaphragm is divided into the lumbar, costal and sternal parts. The l u m b a r   p a r t originates from the r i g h t and l e f t   c r u s e s from the medial and lateral arcuate ligaments and the anterior surface on lumbar vertebrae. The m e d i a l   a r c u a t e   l i g a m e n t (lig. arcuátum mediále) begins from the lateral surface of the L1 vertebra and attaches to the transverse process of the L2 vertebra. This ligament is stretched over the psoas major muscle. The l a t e r a l   a r c u - a t e   l i g a m e n t (lig. arcuátum laterále) stretches between the apex of L2 vertebra and rib 12. It is situated in front of the lumbar quadrate muscle. The two peduncles of the lumbar part of the diaphragm cross each other on the level of L1 vertebra, forming the a o r t i c   h i a t u s (hiátus aórticus) that serves as a passage for the aorta and the thoracic duct. The edges of this opening are limited by fibrous lamina called the m i d d l e   a r c u a t e   l i g a m e n t, which protects the vessels, which pass through this opening from compression. Above and somewhat to the left of the aortic hiatus, in the lumbar part of the diaphragm, is the esophageal hiatus opening (hiátus oesophágeus), which is a passage for the esophagus and vagus nerve. Other vessels and nerves also pass between muscle fascicles of the lumbar part (the azygos and hemiazygos veins, the greater and lesser splanchnic nerves, the sympathetic trunk).

The c o s t a l   p a r t of the diaphragm is formed by muscle fascicles, which originate from the internal surfaces of the lower six-seven ribs and insert into the centarl tendon of the diaphragm.

The s t e r n a l   p a r t is the most narrow. It originates from the posterior surface of the sternum and converges into the central tendon.

There c e n t r a l   t e n d o n has c a v a l   o p e n i n g (forámen vénae cávae).
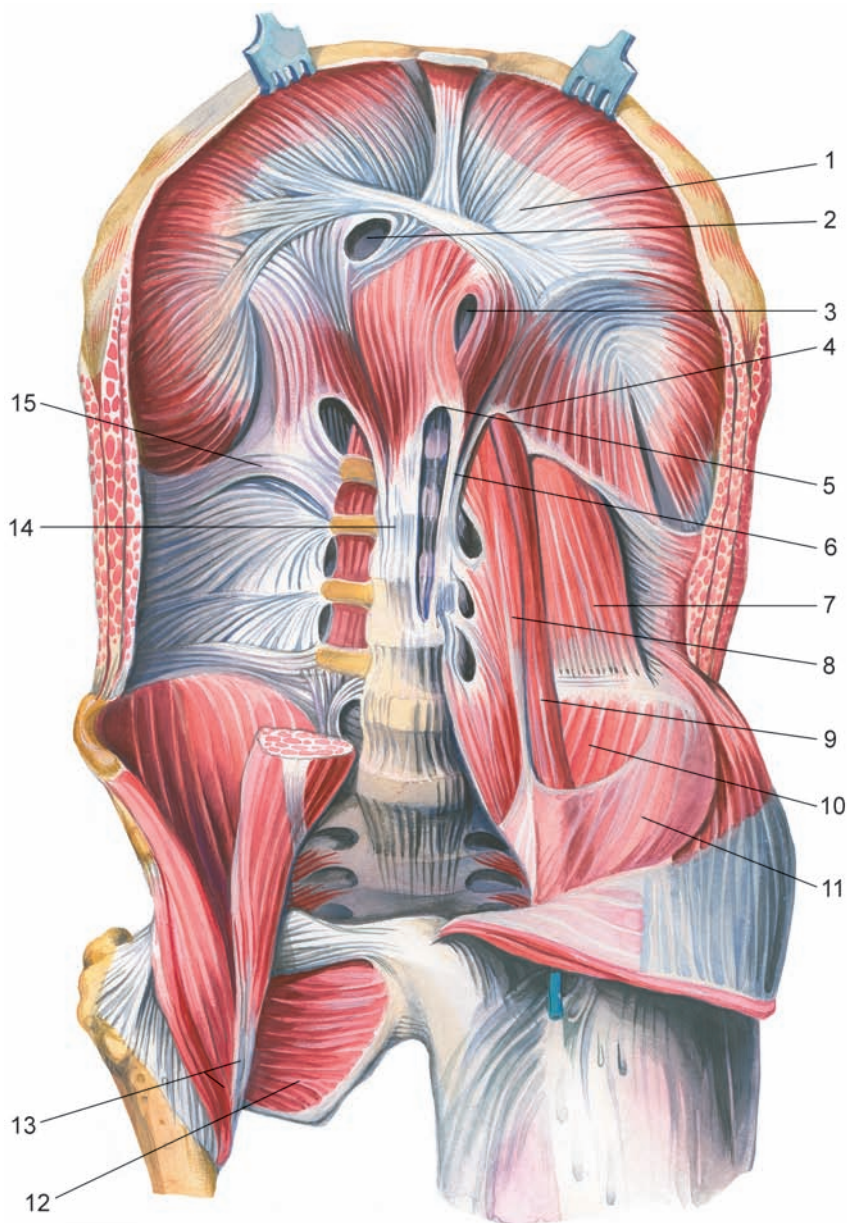
Fig. 97. Diaphragm and posterior abdominal muscles.

1 — central tendon; 2 — caval opening; 3 — oesophageal hiatus; 4 — medial arquate ligament; 5 — aortic hiatus; 6 — left crus of diaphragm; 7 -quadratus lumborum; 8 — psoas minor; 9 — psoas major; 10 — iliacus; 11 — iliac fascia; 12 — obturator externus; 13 — iliopsoas; 14 — right crus of diaphragm; 15 — lateral arquate ligament.

On top the diaphragm is covered by the endothoracic fascia and from below — by the endoabdominal fascia.

The diaphragm has weak places, in which muscle fibers are absent and the organs of the abdominal and thoracic cavities are separated only by the endoabdominal and endothoracic fasciae. These are the paired lumbocostal and sternocostal triangles. The l u m b o c o s t a l t r i a n g l e is situated between lumbar and costal parts of the diaphragm. The s t e r n o c o s t a l t r i - a n g l e is smaller and is situated between sternal and costal parts of the diaphragm. These triangles often become a site of diaphragmatic hernias.

F u n c t i o n: During contraction, the diaphragm flattens and drops down increasing the volume of the thorax. When the diaphragm contracts simultaneously with the muscles of the abdominal press, the intra-abdominal pressure increases.

I n n e r v a t i o n: phrenic nerve.

B l o o d s u p p l y: pericardiacophrenic artery, superior and inferior phrenic arteries, musculophrenic artery, posterior intercostal arteries.

FASCIAE OF THE THORAX

The s u p e r f i c i a l f a s c i a o f t h e c h e s t (fáscia super-ficiális) is weakly developed. The p e c t o r a l f a s c i a (fáscia pec-torális) has deep and superficial laminae. The s u p e r f i c i a l l a m i n a covers the pectoralis major muscle in the front. It attaches medially to the edge of the sternum; laterally it continues into the deltoid fascia; at the bottom it becomes the axillary fascia; and at the top it attaches to the clavicle. The d e e p l a m i n a of the pectoral fascia separates the pectoralis major and pectoralis minor muscle, forming a fascial sheath for the former. Laterally and at the bottom the deep lamina of pectoral fascia merges with the superficial lamina. Between the clavicle and the upper edge of the pectoralis minor the deep lamina has a thickening called the c l a v i p e c t o r a l f a s c i a (fascia clavipectoralis). Beneath this fascia are ribs and external intercostal muscles. The inside of the thorax is lined by the e n d o t h o r a c i c f a s c i a (fáscia endothorácica). It covers the internal intercostal muscles, transverse thoracic muscles, internal surfaces of ribs and the diaphragm.

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE THORAX

The surface of the thorax has several palpable points of reference, including the jugular notch of the sternum, the clavicles, the xiphoid process of the sternum and the ribs. Jugular notch of the sternum corresponds

to the lower edge of the T2 vertebra. The sternal angle projects onto the intervertebral disc between T4 andT5 vertebrae. The lower edge of the body of the sternum is situated at the level of T10 vertebra. In men the contours of the pectoralis major and the d e l t o p e c t o r a l s u l c u s project onto the thoracic wall. In women the mammary gland is situated at the level of ribs 3–7. In very thin people a s e r r a t e d l i n e is visible along the side of the sternum, formed by fascicles of the serratus anterior and external oblique abdominal muscles. The skin of the chest is relatively thin. In men there is hair in the region of the sternum and scapulae. The skin contains many sebaceous and sweat glands in the area of the sternum, on the sides of the thorax and over the scapulae. The subcutaneous fat is moderately developed (more in the female). It contains superficial veins and arterial branches (from internal thoracic, intercostal, lateral thoracic arteries), as well as anterior and lateral branches of the intercostal nerves.

The superficial fascia, which is part of the superficial fascia of the body, forms part of the mammary gland capsule, giving off connective tissue septa, which divide the glands into lobes. Fascicles of the fascia extend from the capsule of the mammary gland to the clavicle. These are known as the s u s p e n s o r y l i g a m e n t s o f t h e b r e a s t (ligg. suspensória mammária).

Behind the pectoralis major and minor muscles there are three areas called the c l a v i p e c t o r a l, p e c t o r a l and s u b p e c t o r a l t r i a n-g l e s. The clavipectoral triangle is defined between the clavicle and the upper edge of the pectoralis minor (at the level of the clavipectoral fascia). Edges of the pectoralis minor muscle limit the pectoral triangle. The subpectoral triangle is defined between the lower edges of the pectoralis minor and pectoralis major muscles. In the region of the sternum the pectoral fascia accretes with its periosteum, forming a thick connective tissue lamina called the anterior sternal membrane.

Between the two pectoral muscles, which lie within fascial sheaths, is a subpectoral fatty tissue space. Beneath the pectoralis minor muscle is the deep fatty tissue space. Both of these are filled by fatty tissue. Between the internal and external intercostal muscles there is a thin layer of loose connective tissue, which contains vessels and nerves that pass along the costal grooves.

Questions for revision and examination

1. Name the muscles, which raise the ribs. What muscles lower the ribs?
2. Do the external and internal intercostal muscles take up the whole length of inter costal spaces? Describe the topographical differences between these two muscles.
3. Name the parts of the diaphragm and its openings.

4. Name the «weak» places in the diaphragm. Where are they situated and what forms their borders.

5. Name the fasciae and fatty tissue spaces of the chest and describe their topographic characteristics.

MUSCLES AND FASCIAE OF THE ABDOMEN

The abdomen (abdomen) is the region between the thorax and pelvis. Its upper border is drawn along the xiphoid process of the sternum, the costal arches and the T12 vertebra. Its lateral border passes from the costal arches, along the posterior axillary line down to the iliac crest. Its lower border is formed by anterior parts of the iliac crests and a provisory line that corresponds to the inguinal folds.

The abdominal muscles form the anterior, posterior and lateral walls of the abdominal cavity. According to their topography these muscles are divided into anterior, posterior and lateral.

Muscles of the anterior and lateral abdominal walls

This group of muscles includes the internal and external oblique muscles, transverse abdominal muscle, rectus abdominis and pyramidalis muscles. The oblique and transverse abdominal muscles are situated in layers, their muscular fibers oriented in different directions. The rectus abdominis and pyramidalis muscles are oriented longitudinally.

The external oblique muscle of the abdomen (m. oblíquus extérnus abdóminis) is situated superficially. It originates by muscle serrations on lateral surfaces on the lower 8th-9th ribs. The five upper serrations pass between serrations of the serratus anterior muscle, and the three lower ones — between serrations of the latissimus dorsi muscle. Its fascicles stretch down and medial, continuing into a wide flat aponeurosis. The upper and middle fascicles of the aponeurosis reach the anterior middle line, where they accrete with the aponeurosis of the opposite side, taking part in formation of the white line of the abdomen. The lower fascicles attach to the external lip of the iliac crest and the pubic tubercle, forming between them a thickened tendinous cord called the i n g u i n a l l i g a m e n t (lig. inguinále).

F u n c t i o n: During bilateral contraction this muscle lowers the ribs and bends the spine. During unilateral contraction it turns body to the opposite side. When the lower extremities are not fixed it lifts the pelvis forward. It is one of the muscles of the prelum abdominale muscles.

I n n e r v a t i o n: intercostal nerves (5–12), iliohypogastric nerve, ilioinguinal nerve.

B l o o d s u p p l y: posterior intercostal and lumbar arteries, lateral thoracic artery, superficial circumflex iliac artery.

The internal oblique muscle of the abdomen (m. obliquus internus abdominis) is situated beneath the external oblique muscle. It originates on the lateral two thirds of the inguinal ligament, the anterior two thirds of the intermediate line of the iliac crest and on the thoracolumbar fascia. Its fascicles stretch upwards, diverge like a fan and continue into a wide aponeurosis. The upper fascicles of the aponeurosis attach to cartilages of the lower ribs. The middle fascicles stretch medially and lower — obliquely downwards and to the front. The middle and lower tendinous fascicles of the left and right aponeurosis of this muscle participate in the formation of the white line of the abdomen.

F u n c t i o n: When the pelvis is fixed, bilateral contraction of this muscle bends the vertebral column and lowers the ribs. During unilateral contraction (simultaneously with the external oblique muscle of the abdomen on the opposite side) the body is turned to the same side. When the thorax is fixed it lifts the pelvis to the front. It is a muscle of the prelum abdominale.

I n n e r v a t i o n: intercostal nerves (6–12), iliohypogastric nerve, ilioinguinal nerve.

B l o o d s u p p l y: posterior intercostal and lumbar arteries, superior and inferior epigastric arteries, musculophrenic artery.

The transverse abdominal muscle (m. transvérsus abdóminis) forms the deepest muscle layer of the lateral abdominal walls. It originates on the internal surface of the lower six ribs, the deep lamina of the lumbothoracic fascia, the anterior part of the internal lip of the iliac crest and on the lateral part of the inguinal ligament. Its fascicles stretch transversely medial and to the front. At the level of the lateral edge of rectus abdominis it continues into a wide aponeurosis, which passes along the semilunar line.

The lower fascicles of the internal oblique and transverse muscles of abdomen participate in the formation of the testicular cord as the c r e m a s t e r m u s c l e (m. c r e m á s t e r.)

F u n c t i o n: brings the lower ribs down and to the front; decreases the size of the abdominal cavity, forms part of the prelum abdominale.

I n n e r v a t i o n: intercostal nerves (5–12), iliohypogastric and ilioinguinal nerves.

B l o o d s u p p l y: intercostal and lumbar arteries, superior and epigastric arteries, musculophrenic artery.

The rectus abdominis muscle (m. réctus abdóminis) is a paired flattened strap muscle, situated at either side of the anterior middle line. The two rectus abdominis muscles are separated by the l i n e a a l b a of the abdomen. The origin of these muscles is on the pubic crest and the

pubic symphysis. The rectus abdominis stretches upward and inserts on the anterior surface of the xiphoid process and costal cartilages of ribs V–VII. It is divided into segments by 3–4 horizontal t e n d i n o u s   i n t e r s e c - t i o n s, which are residuals of the embryonic intersegment membranes.

F u n c t i o n: When the spine and pelvic girdle are fixed, this muscle pulls the ribs down, lowering the thorax. Otherwise it causes flexion of the vertebral column (trunk), and with a fixed thorax it raises the pelvis.

I n n e r v a t i o n: intercostal nerves (7–12), iliohypogastric nerve.

B l o o d   s u p p l y: superior and inferior epigastric arteries, posterior intercostal and lumbar arteries.

The pyramidalis muscle (m. pyramidális) is paired, triangularly shaped, and is situated in front of the lower section of the rectus abdominis muscle. It originates from the pubic crest and inserts into the linea alba of abdomen. This muscle is often absent.

F u n c t i o n: stretches the linea alba of the abdomen.

I n n e r v a t i o n: iliohypogastric nerve.

B l o o d   s u p p l y: inferior epigastric artery.

MUSCLES OF THE POSTERIOR ABDOMINAL WALL

The posterior abdominal wall is formed by the paired quadratus lumborum muscle and the psoas major and minor muscles, all of which are situated at the sides of the vertebral column.

The quadratus lumborum muscle (m. quadrátus lumbórum) originates from the iliac crest, iliolumbar ligament and the transverse processes of lower lumbar vertebrae. The muscle stretches upwards and inserts into the lower edge of the last rib and the transverse processes of the upper lumbar vertebrae.

F u n c t i o n: During bilateral contraction it helps support the trunk in an upright position. Lateral contraction causes the spine to bend to the corresponding side and pulls the twelfth rib down.

I n n e r v a t i o n: muscular branches of the lumbar plexus.

B l o o d   s u p p l y: lumbar arteries, iliolumbar artery.

The psoas major muscle (m. psóas májor) is long, fusiform, and is situated medial and to the front of the lumbar quadrate muscle. It originates from the lateral surfaces of the bodies of lumbar vertebrae and the transverse processes of T12 and L1–L4 vertebrae. Towards the bottom it becomes narrow and merges with fascicles of the i l i a c   m u s c l e. Together they form a common iliopsoas muscle, which attaches to the greater trochanter of the femur (see «Muscles of the lower extremities»).

F u n c t i o n: Participates in flexion of the femur in the coxal joint.

I n n e r v a t i o n: muscular branches of the lumbar plexus.

B l o o d s u p p l y: lumbar arteries.

The psoas minor muscle (m. psóas mínor) is thin, fusiform, situated on the anterior surface of the psoas major muscle. It originates from the lateral surface of the T12 and L1 vertebrae. It inserts into the iliac fascia, the pubic crest and iliopubic eminence.

F u n c t i o n: This muscle tightens the iliac fascia.

I n n e r v a t i o n: muscular branches of lumbar plexus.

B l o o d s u p p l y: lumbar arteries.

Muscles of abdomen are demonstrated in the table 10.

Table 10. Muscles of the abdomen.

Muscle	Origin	Insertion	Action	Innervation
Muscles of the lateral abdominal walls				
External oblique	External surface of ribs 5-12	External lip of iliac crest, pubic symphysis and linea alba of abdomen	Turns the trunk to opposite side; bilateral contraction lowers ribs and bends the spine	Ilioinguinal, iliohypogastric and lower intercostal nerves
Internal oblique	Intermediate line of iliac crest, inguinal ligament and thoracolumbar fascia	Cartilages of lower ribs and linea alba of abdomen	Turns body to same side, lowers the ribs and bends the spine	Same as above
Transverse abdominal	Inferior surfaces of ribs 6–12, internal lip of iliac crest, thoracolumbar fascia and inguinal ligament	Linea alba of abdomen	Bilateral contraction decreases the volume of the abdominal cavity	Same as above
Muscles of the anterior abdominal wall				
Rectus abdominis	Pubic crest and pubic symphysis	Cartilages of ribs 5–7 and xiphoid process of sternum	Pulls ribs and sternum downward, bends the vertebral column; when thorax is fixed it raises the pelvis	Iliohypogastric and lower intercostal nerves
Pyramidalis	Pubic crest	Linea alba of abdomen	Stretches white line of abdomen	Same as above
Muscles of the posterior abdominal wall				
Quadratus lumborum	Iliac crest and transverse processes of lower lumbar vertebrae	Rib 12 and transverse processes of L1–L4 vertebrae	Bends spine sideways, supports it in vertical position	Muscular branches of lumbar plexus

FASCIAE OF THE ABDOMINAL REGION

The s u p e r f i c i a l   f a s c i a separates the abdominal muscles from the subcutaneous fatty tissue. The p r o p e r   f a s c i a of abdomen consists of several laminae distributed among the muscular layers of the abdomen. The best developed of these is the lamina, which covers the external oblique muscle. The t r a n s v e r s a l i s   f a s c i a covers the anterior and lateral walls of the abdominal cavity, making up a large part of the i n t r a-a b d o m i n a l   f a s c i a. On the inside of the abdomen the transversalis fascia is covered by the peritoneum.

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE ABDOMINAL WALLS

The skin of the abdomen is thin, versatile and relatively elastic. The state of development of subcutaneous fatty tissue may vary between individuals. The superficial fascia of the abdomen is a continuation of the pectoral superficial fascia. It is weakly developed in the upper parts of the abdomen, but is thicker in the inguinal regions, where it accretes with the inguinal ligaments. In the region of the alba line the superficial fascia accretes with the skin by tendinous fibers, which sometimes divide the subcutaneous fatty tissue of the anterior abdominal wall into right and left halves. Because of this the skin above the alba line is not as movable. Beneath the superficial fascia there is a layer of fatty tissue, the thickness of which may vary.

In the region of the s u p e r f i c i a l   i n g u i n a l   r i n g (ánulus) the proper fascia participates in the formation of the i n t e r c r u r a l   f i b e r s. The fibers of this fascia continue onto the spermatic cord as the fascia of the cremaster muscle. The other laminae of the proper fascia, which cover the internal oblique and transverse abdominal muscle, accrete with their perimysium. Between these two muscles there is a thin space of fatty tissue, which contains intercostal nerves and blood vessels. The transversalis fascia covers the inside surface of the transverse abdominal muscle and part of the facial sheath of the rectus abdominis muscle. This fascia is relatively thick in the inguinal region, where it attaches to the inguinal ligament and the internal lip of the iliac crest. About 1.5 cm above the midpoint of the inguinal ligament the transversalis fascia forms oval depression, which is the superficial inguinal ring. On the inside surface of the anterior abdominal wall, on either side of the middle line, there are three fossae, separated from each other by folds of the peritoneum. The

most medial is the s u p r a v e s i c a l f o s s a (fóssa supravesicalis), situated between the middle and medial umbilical folds. The medial umbilical fold is formed by an obliterated umbilical artery. The m e d i a l i n g u i n a l f o s s a (fóssa inguinális mediális) is situated between the medial and lateral umbilical folds. The lateral fold is formed over the inferior epigastric artery. The l a t e r a l i n g u i n a l f o s s a (fóssa inguinális laterális) lies to the outside of the lateral umbilical fold.

Between the transverse abdominal fascia and the parietal peritoneum there is a preperitoneal fatty tissue space, filled by loose fibrous and fatty tissues.

On the posterior abdominal wall, behind the quadratus lumborum muscle is the deep lamina of the thoracolumbar fascia and the origin of the erector muscle of the spine.

At the top the facial sheath of the quadratus lumborum muscle attaches to the twelfth rib and accretes with a tendinous arch, which is stretched between this rib and the L1 vertebra. At the bottom the facial covering accretes with the periosteum of the iliac bone and lateral part of the sacrum. Behind the quadratus lumborum muscle and the deep lamina of the yhoracolumbar fascia is the lumbar quadrangle. It is bordered by the twelfth rib and lower edge of inferior posterior serratus muscle at the top; the upper medial edge of the internal oblique muscle at the bottom; medially — by the sacrospinal muscle; and laterally by posterior edge of the external oblique muscle. The thick fascia of the major psoas muscle attaches medially to anterolateral surface of the lumbar vertebrae, and laterally — to their transverse processes. This fascia forms part of the osteofibrous bed for the psoas major and minor and the iliac muscles.

Linea alba of the abdomen

The white line of the abdomen (línea álba) is a compact connective tissue plate, which stretches along the anterior middle line from the xiphoid process to the pubic symphysis. The linea alba is formed by crossing fibers of the aponeuroses of abdominal muscles. In the middle of the linea alba is the u m b i l i c a l r i n g (anulus umbilicalis). This ring is an occluded opening, which during the prenatal period is a passage for blood vessels that link the circulatory systems of the fetus and the mother. These vessels stop functioning after birth. Above the umbilicus the linea alba is relatively wide, whereas towards the bottom it narrows and becomes thicker. In an adult its width varies between 2 and 4 cm.

The rectus sheath

The rectus sheath (vagína m. récti abdóminis) is found on either side of the linea alba (white line) of the abdomen. It serves as a casing for the rectus and pyramidal muscles of the abdomen (Fig. 98). It is formed by the aponeuroses of the oblique and transverse abdominal muscles. It has an a n t e r i o r   l a y e r and a p o s t e r i o r   l a y e r (walls), which have different structures. The rectus sheath can be divided into lower and upper parts. In the upper part, which extends 2–5 cm below the umbilicus, the anterior wall is formed by the aponeurosis of the external oblique muscle and the external lamina of the aponeurosis of the internal oblique muscle. The posterior wall is formed by the internal lamina of the internal oblique muscle, aponeurosis of the transverse abdominal muscle, the intra-abdominal fascia and the peritoneum. In the lower part the anterior wall of the rectus sheath is formed by aponeuroses of the external and internal oblique and transversal abdominal muscles. The posterior wall is formed only by the transversalis fascia and the peritoneum. The border between
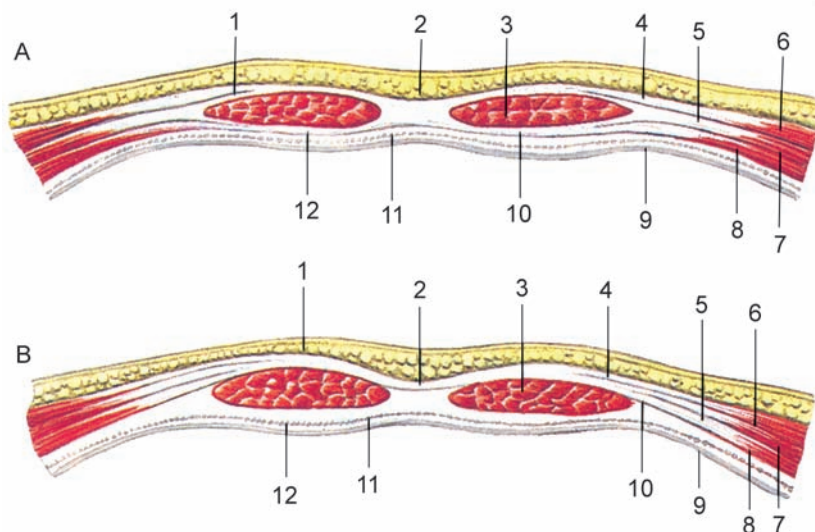
Fig. 98. Structure of sheath of rectus abdominis in its upper 2/3(A) and lower 1/3(B), transverse section.

1 — anterior layer of sheath of rectus abdominis; 2 — linea alba; 3 — rectus abdominis; 4 — aponeurosis of external oblique; 5 — aponeurosis of internal oblique; 6 — external oblique; 7 — internal oblique (of abdomen); 8 — transversus abdominis; 9 — peritoneum; 10 — aponeurosis of transversus abdominis; 11 — transversalis fascia; 12 — posterior layer of rectus abdominis.
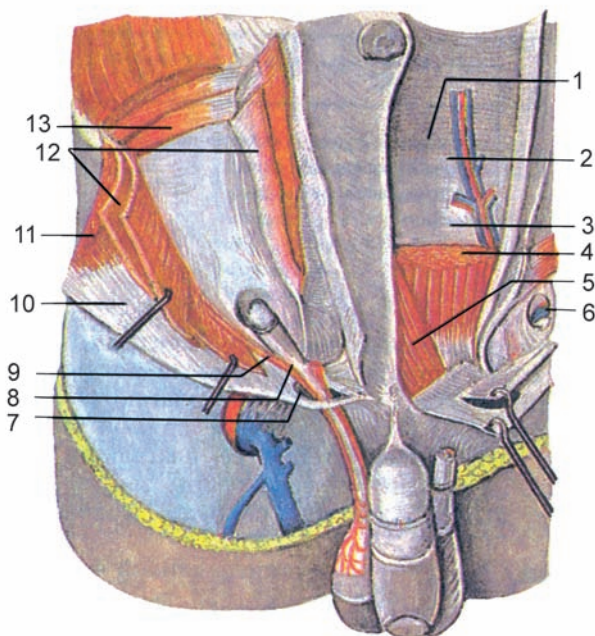
Fig. 99. Canalis inguinalis. From the right muscles of abdomen are cut and pulled away. From the left rectus sheath abdominis muscle is opened and the urogenital diaphragm partially removed.

1 — rectus sheath (posterior layer); 2 — arcuate line; 3 — transversalis fascia; 4 — rectus abdominis; 5 — pyramidalis; 6 — deep inguinal ring; 7 — superficial inguinal ring; 8 — spermatic cord; 9 — cremaster, 10 — aponeurosis of external oblique muscle (of abdomen); 11 — external oblique; 12 — internal oblique; 13 — transversus abdominis.

lower and upper parts of the posterior wall of the rectus sheath corresponds to the border between aponeuroses of the transversal abdominal and internal oblique muscles. This border is called the a r c u a t e (D o u - g l a s) l i n e (línea arcuáta, s. línea semilunáris). Below the arcuate line the aponeuroses of the oblique and transverse abdominal muscles are situated in front of the rectus abdominis muscle, while behind it is only the transversalis fascia. In this part of the abdomen the right and left rectus sheaths are communicated with each other.

Between the posterior surface of the rectus abdominis and the posterior wall of its sheath there is a thin narrow longitudinal fatty tissue space, which contains the epigastric arteries and veins and the terminal branches of lower intercostal nerves and arteries.

The inguinal canal

The inguinal canal (canális inguinális) is situated on both sides, directly above the medial half of each inguinal ligament, lateral of the rectus sheath (Fig. 99). It is a narrow slit 4–6 cm long, which passes obliquely down and medially through the anterior abdominal wall from the deep (inner) inguinal ring to the superficial (subcutaneus) inguinal ring. This canal is a passage for the testicular cord (in men) or the round ligament of the uterus (in women). The inguinal canal is the usual site of the formation of strait and oblique ingunal hernias.

The d e e p i n g u i n a l r i n g (ánulus inguinális profúndus) is situated in the region of the lateral inguinal fossa in the form of an infundibular recess in the transverse fascia of the abdomen. The s u p e r ficial inguinal ring (ánulus inguinális superficiaális) is situated beneath the skin between medial and lateral crura of the aponeurosis of the external oblique muscle, above the superior ramus of the pubis. The superficial ring is bordered by the medial crus at the top, the lateral crus at the bottom, the intercrural fibers on the lateral side and by the retroflexed ligament medially. The inguinal canal has 4 walls: anterior, posterior, superior and inferior. The anterior wall is formed by the aponeurosis of the external oblique muscle; the posterior wall — by the transverse fascia; the superior wall — by the lower edges of the internal oblique and transverse abdominal muscles; and the inferior wall is formed by the inguinal ligament.

Questions for revision and examination

1. What functional significance can be given to the mutually opposing orientation of the external and internal oblique muscles of the abdomen?

2. What are the tendinous inscriptions of the rectus abdominis muscle derived from?

3. What is the white line of the abdomen? What differences in structure are there between its lower and upper parts?

4. Describe the structure of the anterior and posterior walls of the rectus sheath.

5. Name the weak places of the anterior abdominal wall and walls of the inguinal canal. Name the folds and fossae found on the inner surface of the anterior abdominal wall.

6. Describe the topography and structure of the walls of the superficial and deep inguinal rings.

7. Describe the fasciae and fatty tissue spaces of the walls of the abdomen.

MUSCLES AND FASCIAE OF THE HEAD

Muscles of the head are divided into muscles of facial expression and muscles of mastication.

MUSCLES OF FACIAL EXPRESSION

The muscles of facial expression have certain special characteristics. They develop from the mesenchyme of the second visceral arch and are located directly beneath the skin, not covered by a fascia. The orientation of their fascicles corresponds to the natural openings of the head (face), meaning they are oriented mainly in a radial or circular direction. The circular fibers serve to narrow, or close the openings and are called sphincters. The radial fibers enlarge the openings, acting as dilators. The muscles of facial expression originate from the surfaces of the bones of the skull and insert into the skin. Contraction of these muscles reflects the inner condition of the person, forming facial expressions (smiling, sadness, fear and other emotions). These muscles are divided according to their topography into the muscles of the roof of the skull, muscles of the eyelid and orbit, muscles of the nose, muscles of the mouth and muscles of the auricular concha (Fig. 100). All muscles of facial expression are innervated by the facial nerve, which is the nerve of the second visceral arch.

Muscles of the roof of the skull

The occipitofrontalis muscle (m. occipitofrontális) covers the roof of the skull, and consists of an o c c i p i t a l b e l l y and a f r o n t a l b e l l y. The occipital belly originates from the superior nuchal line and the bases of the mastoid processes. It stretches upward towards the front, and continues into an aponeurosis called the g a l e a a p o n e u r o t i c a. The frontal belly originates from the same aponeurosis and is inserted into the skin of the eyebrows.

F u n c t i o n: The occipital belly pulls the skin of the head to the back, creating a support for the frontal belly. During contraction of the frontal venter the skin of the forehead forms transverse folds and the eyebrows are lifted, giving the face an expression of surprise.

B l o o d s u p p l y: occipital, posterior auricular, superficial temporal and supraorbital arteries.

The temporoparietalis muscle (m. temporoparietális) is situated on the lateral surface of the skull and is weakly developed. Separate muscular fibers stretch forward from the cartilage of the auricular concha, spread out and are inserted into the lateral parts of galea aponeurotica. The functioning of this muscle is insignificant.

B l o o d s u p p l y: superficial temporal artery.

The procerus muscle (m. procerus) originates from the exterior surface of the nasal bone and inserts into the skin of the forehead.

F u n c t i o n: Forms transverse folds at the root of the nose, at the same time straightening these folds on the forehead.

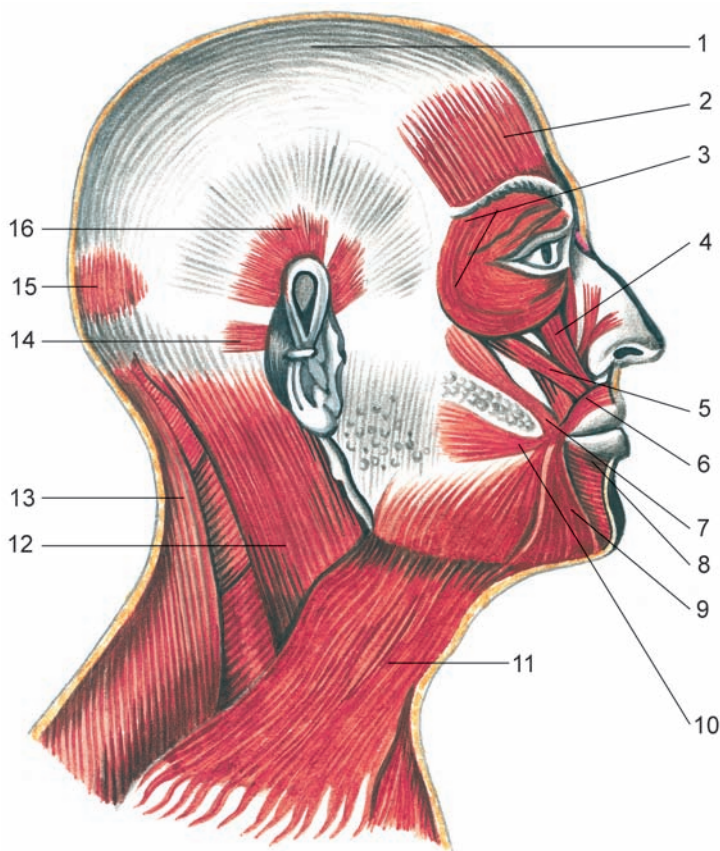B l o o d s u p p l y: angular artery, frontal artery.

Fig. 100. Muscles of head and neck. Right aspect.

1 — epicranius (occipitofrontalis); 2 — frontal belly (of occipitofrontalis); 3 — orbicularis oculi; 4 — levator labii superioris; 5 — levator anguli oris; 6 — orbicularis oris; 7 — zygomaticus major; 8 — depressor labii inferioris; 9 — depressor anguli oris; 10 — risorius; 11 — platysma; 12 — sterno-cleidomastoid; 13 — trapezium; 14 — auricularis posterior; 15 — occipital belly (of occipitofrontalis); 16 — auricularis superior.

Muscles of the eyelid and the orbit

The orbicularis oculi muscle (m. orbiculáris óculi) is situated around the orbit, within the eyelids. This muscle is divided into the palpebral, ocular and lacrimal parts.

The p a l p e b r a l   p a r t is formed by muscle fibers, which originate from the medial palpebral ligament and stretch over the anterior surface of the cartilages of the superior and inferior eyelids to the lateral corner of the eye. These fibers form the lateral raphe palpebralis and insert into the periosteum of the lateral wall of the orbit.

The o r b i t a l p a r t originates from the frontal process of maxilla, the nasal part of the frontal bone and the medial palpebral ligament. Its fibers stretch along the superior and inferior margins of the orbit to its lateral wall, where the upper and lower fibers continue into each other.

The l a c r i m a l p a r t of the muscle originates from the lacrimal crest and lateral surface of the lacrimal bone. Its fibers pass behind the lacrimal sac and are inserted into the palpebral part of the orbicularis oculi muscle.

F u n c t i o n: The palpebral part of this muscle shuts the eyelids. The orbital part closes the eye tightly, squinting it, and thus causing radial folds to form at its lateral corner. The lacrimal part widens the lacrimal sac, regulating the outflow of tears into the nasolacrimal duct.

B l o o d s u p p l y: facial, superficial temporal, infraorbital and supraorbital arteries.

The corrugator supercilii muscle (m. corrugátor supercílii) originates from the medial part of the brow ridge, stretches upward and lateral and is inserted into the skin of the eyebrow.

F u n c t i o n: It corrugates the eyebrow, forming vertical folds above the root of the nose.

B l o o d s u p p l y: frontal, supraorbital and superficial temporal arteries.

Muscles of the nose

The nasalis muscle (m. nasális) consists of the transverse and alar parts.

The t r a n s v e r s e p a r t originates above and laterally of the incisors of the maxilla. Its muscle fibers stretch upward and medial and continue into a thin aponeurosis, which overlaps the nasal spine and fuses with the transversal part of the other side.

The a l a r p a r t originates on the maxillae, below and medial of the transverse part, and is inserted into the skin of the ala nasi.

F u n c t i o n: The transverse part narrows the nostrils. The alar part widens the nostrils, pulling the ala nasi down and to the side.

B l o o d s u p p l y: the superior labial artery, angular artery.

The depressor septi nasi muscle (m. depréssor sépti nási) originates above the medial incisor of the maxilla and is inserted into the cartilaginous nasal septum.

F u n c t i o n: Pulls the nasal septum down.

B l o o d s u p p l y: superior labial artery.

Muscles of the mouth

The orbicularis oris muscle (m. orbiculáris óris) forms the muscles of the lips. It consists of marginal and labial parts.

The m a r g i n a l   p a r t (peripheral part of the orbicularis oris) is formed by fascicles of the neighboring muscles of facial expression. The l a b i a l   p a r t is the central part of this muscle. It consists of muscle fascicles that stretch from one corner of the mouth to the other.

F u n c t i o n: It closes the mouth, takes part in chewing and sucking.

B l o o d   s u p p l y: superior and inferior labial arteries, submental artery.

The depressor anguli oris muscle (m. depréssor ánuguli óris) originates on the mandible, between the submental protuberance and the region of the first premolar tooth. Its fibers insert into the skin of the corner of the mouth.

F u n c t i o n: Pulls the corner of the mouth down and to the side.

B l o o d   s u p p l y: inferior labial artery, submental artery.

The depressor labii inferioris muscle (m. depréssor lábii inferi-óris) originates on the base on the mandible. It is partially covered by the depressor anguli oris muscle. Its fascicles stretch upwards and medially and are inserted into the skin and mucosa of the lower lip.

F u n c t i o n: It pulls the lower lip downward and lateral. With bilateral constriction it turns the lip inside out (expression of disgust).

B l o o d   s u p p l y: inferior labial artery, submental artery.

The mentalis muscle (m. mentális): originates on the alveolar eminencies of the incisors of mandible, stretches downward and medial, unites with the muscle fibers of the paired muscle and inserts into the skin of the chin.

F u n c t i o n: Pulls the skin of the chin upward and lateral, forms a fossula on the chin and participates in pulling the lower lip forward.

B l o o d   s u p p l y: inferior labial artery and submental artery.

The cheek muscle, or buccinator (m. buccinátor) forms the muscular base of the cheek. It originates on the oblique line of mandible, the outer surface of the alveolar arch of maxilla on the level of the molars, and the anterior part of the pterygomandibular raphe. Its fascicles stretch to the angle of mouth, cross over each other and continue into the muscles of lips. On the level of the second molar the buccinator is perforated by the parotid duct.

F u n c t i o n: Pulls the corner of the mouth to the back and pushes the cheeks against the teeth.

B l o o d   s u p p l y: buccal artery.

The levátor labii superioris muscle (m. levátor lábii superióris) arises from the infraorbital margin of maxilla, stretches downward and is inserted into the upper lip.

F u n c t i o n: This muscle lifts the upper lip. It forms the groove between the nose and the lip and pulls the ala nasi upward.

B l o o d   s u p p l y: infraorbital artery and superior labial artery.

The zygomatic major muscle (m. zygomáticus májor) originates on the lateral surface of the zygomatic bone and is inserted into the corner of the mouth.

F u n c t i o n: It pulls the corner of the mouth up and to the side and is the main muscle used during laughter.

B l o o d   s u p p l y: infraorbital artery, buccal artery.

The zygomatic minor muscle (m. zygomáticus mínor) originates on the zygomatic bone besides the lateral edge of the levator labii superioris. Its fascicles stretch downward and medial and are inserted into the skin of the corner of the mouth.

F u n c t i o n: Lifts the corner of the mouth.

B l o o d   s u p p l y: infraorbital artery, buccal artery.

The levator anguli oris muscle (m. levátor ánguli óris; m. canínus — BNA) originates on the anterior surface of maxilla, in the region of the canine fossa, and inserts into the corner of the mouth.

F u n c t i o n: It pulls the corner of the mouth up and to the side.

B l o o d   s u p p l y: infraorbital artery.

The risorius muscle (m. risórius) originates from the masticatory fascia and is inserted into the skin of the angle of mouth. It is sometimes absent.

F u n c t i o n: It pulls the angle of mouth laterally, forming a dimple on the cheek.

B l o o d   s u p p l y: facial artery, transverse facial artery.

Muscles of the auricular concha

These muscles include the auricularis anterior, superior and posterior muscles. In the human they are usually weakly developed.

The auricularis anterior muscle (m. auriculáris antérior) originates as a thin fascicle on the galea aponeurotica and the temporal fascia. It stretches down and to the back and inserts into the skin of the auricular concha. It is often absent.

F u n c t i o n: It pulls the auricular concha forward.

The auricularis superior muscle (m. auriculáris supérior) originates as a thin fascicle on the galea aponeurotica, above the auricular concha. It is inserted on the upper part of the cartilage. It may be absent.

F u n c t i o n: Pulls the auricular concha upward.

The auricularis posterior muscle (m. auriculáris postérior) originates from the mastoid process and is inserted into the posterior surface of the concha. It is usually better developed than the other auricular muscles.

F u n c t i o n: This muscle can pull the concha to the back.

B l o o d   s u p p l y: auricularis anterior and superior muscles—superficial temporal artery; auricularis posterior muscle — posterior auricular artery.

Muscles of the face are demonstrated in the table 11.

Table 11. Muscles of facial expression.

Muscle	Origin	Insertion	Action

Occipitofrontalis:
    Occipital part
 	
    Frontal part
	Superior nuchal line and base of mastoid process
	Galea aponeurotica
		Galea aponeurotica
		
		Skin of eyebrows
			Pulls the skin of the skull backward
			Raises eyebrows, forming transverse folds on skin of the forehead

Temporoparietalis	Galea aponeurotica	Base of ear concha	Rudimentary
Corrugator supercilii	Medial part of superciliary arch	Skin of eyebrows	Pulls eyebrows toward the median line, forming vertical folds above the nose bridge
Procerus	Nasal bone	Skin between eyebrows	Forms transverse folds between eyebrows

Orbicularis oculi:
    Orbital part
 	
    Palpebral part
 	
    Lacrimal part
	Nasal part of frontal bone, frontal process of maxilla and medial palpebral ligament
	Medial palpebral ligament
	Lacrimal bone
		Surrounds the palpebral fissure and is inserted near the origin
		
		Lateral palpebral ligament
		Lacrimal sac
			Closes the eye tightly (squinting)
			
			Closes eyelids
			
			Dilates lacrimal sac

Nasalis muscle:
    Transverse part
 	
    Alar part
	Maxilla, above and lateral of superior incisors
	Maxilla, lateral of superior incisors
		Aponeurosis of the dorsum of nose
		
		Skin of wing of nose
			Narrows nostrils
			
			Lowers the wing of nose

Depressor septi nasi	Maxilla, above central incisor	Cartilage part of nasal septum	Pulls the nasal septum downward

Orbicularis oris	Buccinator muscle and skin of the angles of mouth	Skin and mucosa of superior and inferior lips	Closes mouth, draws lips forward
Levator labii superioris	Infraorbital part of maxilla	Skin of upper lip	Raises upper lip
Levator anguli oris	Canine fossa of muscle	Angle of mouth	Raises angle of mouth
Zygomatic major and minor	Zygomatic bone	Angle of mouth	Raises angle of mouth, deepens nasolabial fold
Risorius	Fascial of buccinator muscle	Skin of mouth angle	Stretches mouth angle laterally, forms dimples on cheeks
Buccinator	Maxilla and mandible, pterygomandibular raphe	Orbicular muscle of mouth	Tenses cheek and pulls the angle of mouth backward
Depressor labii inferioris	Inferior margin of mandible	Skin and mucosa of lower lip	Pulls lower lip downward
Depressor anguli oris	Same as above	Skin of mouth angle	Pulls angle of mouth downward
Mentalis	Walls of the alveoli of inferior incisors	Skin of the chin	Pulls the skin of the chin upward
Platysma	See table 13		

MASTICATORY MUSCLES

The muscles of mastication are derivatives of the first visceral arch. They act upon the temporomandibular joint, bringing the mandible into motion. These muscles participate in production of speech, in chewing and swallowing. This group of muscles includes the masseter, temporal, and lateral and medial pterygoid muscles. All muscles of mastication are innervated by the third branch of the trigeminal nerve.

The masseter (m. masséter) consists of superficial and deep parts. The s u p e r f i c i a l p a r t is larger; it originates on zygomatic process of maxilla and anterior part of the zygomatic arch (Fig. 101). It stretches downward and to the back and is inserted on the masseteric tuberosity of the mandible. The d e e p p a r t of this muscle is partly covered by the superficial part; it originates on the lower edge and internal surface of the zygomatic arch. Its fascicles stretch almost vertically down. Both parts are inserted on the external surface of the ramus and the angle of the mandible (to the masseteric tuberosity).
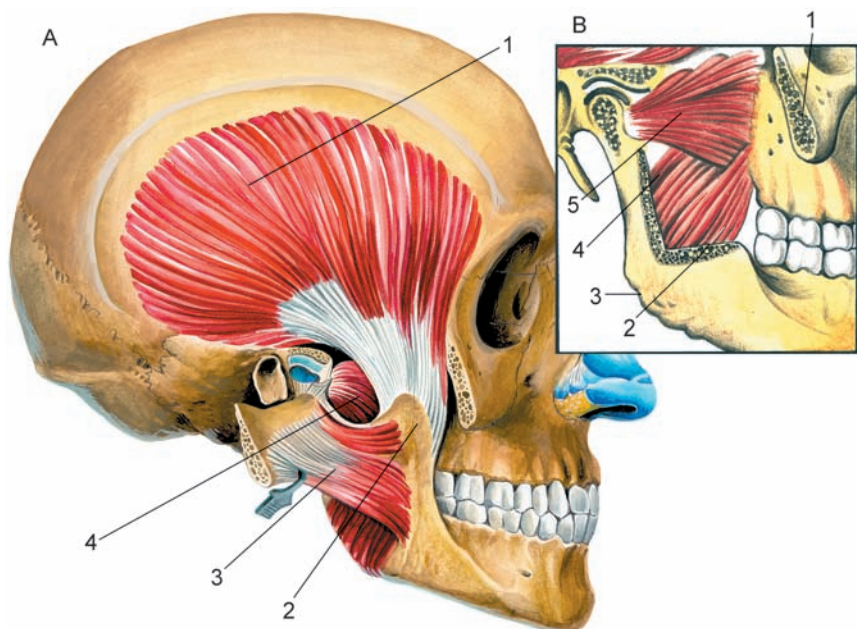
Fig. 101. Masticatory muscles. Right aspect.

A — zygomatic arch sawed off and pulled aside with masseter: 1 — temporal muscle; 2 — coronoid process of mandible; 3 — masseter; 4 — lateral pterygoid. B — zygomatic arch and part of ramus of mandible are removed: 1 — zygomatic arch (sawed off); 2 — medial pterygoid; 3 — angle of mandible; 4 — ramus of mandible; 5 — lateral pterygoid.

F u n c t i o n: This muscle raises the mandible. The superficial part participates in protraction of the lower jaw.

B l o o d s u p p l y: masseteric artery, transverse facial artery.

The temporal muscle (m. temporális) occupies the surface of the temporal fossa and the internal surface of the temporal fascia. Its fascicles stretch downward, continuing into a tendon, which attaches to the coronoid process of the mandible.

F u n c t i o n: It lifts the mandible. Its posterior fascicles retract the lower jaw.

B l o o d s u p p l y: deep and superficial temporal arteries.

The medial pterygoid muscle (m. pterygoídeus mediális) originates in the pterygoid fossa of the pterygoid process. Its muscle fascicles stretch downwards, laterally and to the back. They are inserted on the pterygoid tuberosity of mandible.

F u n c t i o n: Lifts the mandible.

B l o o d s u p p l y: pterygoid branches of the maxillary artery, facial artery.

The lateral pterygoid muscle (m. pterygoídeus laterális) is short and thick. It has two heads of origin — the upper and lower. The u p p e r h e a d originates from the maxillary surface and infratemporal crest of the sphenoid bone; the l o w e r h e a d — from the external surface of lateral lamina of the pterygoid process. The two heads join each other, the fascicles stretch to the back and laterally and are inserted into the neck of the articular process of the mandible, articular capsule and articular disc of the temporomandibular joint.

F u n c t i o n: During bilateral contraction the lower jaw is protracted. During unilateral contraction the muscle pulls the mandible to the opposite side.

B l o o d s u p p l y: pterygoid branches of maxillary artery, facial artery.

Masticatory muscles are demonstrated in the table 12.

Table 12. Muscles of mastication.

Muscle	Origin	Insertion	Action
Masseter	Lower edge of zygomatic bone	Masseteric tuberosity of mandible	Raises the angle of mandible
Temporal	Temporal surface of frontal bone, squama of temporal bone, greater wing of sphenoid bone, temporal fascia	Coronoid process of mandible	Raises and retracts mandible
Medial pterygoid	Pterygoid fossa of pterygoid process	Pterygoid tuberosity of mandible	Raises angle of mandible
Lateral pterygoid	Infratemporal crest of greater wing of sphenoid bone and lateral lamina of pterygoid process	Neck of mandible; articular disk and capsule of temporomandibular joint	Unilateral contraction pulls mandible to opposite side; bilateral contraction protrudes it forward

FASCIAE OF THE HEAD

The temporal fascia (fáscia temporális) is a thick fibrous lamina, which covers the temporal muscle. This fascia begins on the lateral surface of the skull (on the temporal line) and the galea aponeurotica. Above the zygomatic arch this fascial divides into a deep and superficial layers. The s u p e r f i c i a l l a y e r (lamina) attaches on the lateral surface of the zygomatic arch, and the d e e p l a y e r (lamina) accretes with the inner surface.

The masseteric fascia (fáscia massetérica) covers the masseter muscle, accreting with it. At the top this fascia attaches to the lateral surface of the zygomatic bone and zygomatic arch; in the front it continues into the buccopharyngeal fascia; in the back it accretes with the capsule of the parotid gland. The b u c c o p h a r y n g e a l   f a s c i a (f á s c i a   b u c - c o p h a r ý n g e a) covers the buccinator muscle and accretes with the lateral wall of the pharynx. Between the hamulus of the sphenoid bone and the mandible this fascia has a thickening, which forms the p t e r y g o - m a n d i b u l a r   r a p h e (ráphe pterygomandibularis).

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE HEAD

The skin of the frontoparieto-occipital (pilose) region of the head is tightly accreted with the galea aponeurotica. The subcutaneous fatty tissue contains many vertical connective tissue fibers. For this reason even the smallest intracutaneous arteries of this region do not collapse after traumatic injuries of the head, which leads to profuse bleeding. The galea aponeurotica does not fuse with the periosteum, and therefore the skin above the scalp is movable. In the lateral regions of the head the galea aponeurotica continues into the superficial layer of temporal fascia. Beneath the aponeurosis there is a subaponeurotic space filled with fatty tissue, bordered by points of origin and insertion of the occipitofrontal muscle. Beneath the periosteum of the scalp there is a thin layer of loose connective tissue. The periosteum accretes with the bones of the skull along the suture lines.

The skin of the face is thin; it contains a large number of sweat and sebaceous glands. The superficial fascia is absent on the head. Muscles of facial expression are inserted into the skin. At the same time, each of these muscles is covered by a thin connective tissue fascia. In children, the well-developed subcutaneous fatty tissue forms an adipose body on the buccinator muscle. The buccal adipose body has a temporal, orbital and pterygopalatine processes, along which inflammation processes can spread from the face into the orbit and the cranial cavity. The temporal process of the adipose body penetrates beneath the fascia of the temporal muscle. Its orbital process extends to the inferior orbital fissure. The pterygopalatine process enters the pterygopalatine fossa. Sometimes this process enters the cranial cavity through the medial part of the superior orbital fissure. On the inside the buccinator muscle adjoins with the mucosa of the mouth.

Between the laminae of the temporal fascia there is a small amount of fatty tissue, which contains superficial vessels and nerves of the temporal region. This interfascial fatty tissue continues downwards and to the front,

beyond the temporal region. Together with the superficial plate of the temporal fascia, it passes onto the zygomatic muscles.

Between the temporal fascia and temporal muscle there is a small amount of connective tissue, which continues between the temporal and masseter muscles, and also between the masseter and the lateral surface of the mandible. There is also fatty tissue in the space between the temporal muscle (beneath its fascia) and the external wall of the orbit. This space is communicated with the adipose tissue of the cheek.

The lateral surface of the thick masseteric fascia adjoins with the parotid duct. This duct passes towards the front and opens into the mucosa of the mouth between the upper first and second molars. The deep fatty tissue space of the temporal region is situated between the temporal muscle and the periosteum. This space contains vessels of this region, which extend from the infratemporal fossa.

The region of the infratemporal fossa, next to the lower sections of the temporal and pterygoid muscles, is filled with fatty tissue, which contains vessels and nerves. Fatty tissue fills up the t e m p o r o p t e r y g o i d and i n t e r p t e r y g o i d   s p a c e s, which are communicated with each other. The temporopterygoid space is situated between the temporal and lateral pterygoid muscles. The interpterygoid space lies between the lateral and medial pterygoid muscles, which are covered with their proper fasciae.

The deep region of the face contains a p a r a p h a r y n g e a l   f a t t y t i s s u e   s p a c e of the head. This space is limited from the outside by the pterygoid muscle; on its inside is the lateral wall of the pharynx; in the back it is limited by the prevertebral fascia and muscles. Muscles, which originate from the styloid process (stylopharyngeal, styloglossus and stylohyoid) divide the parapharyngeal space into anterior and posterior sections. The posterior section contains the internal carotid artery, internal jugular vein and four cranial nerves (vagus, accessory, hypoglossal and glossopharyngeal). Next to the internal jugular vein there are lymph nodes. The anterior section of this space is occupied by fatty tissue with small blood vessels.

Questions for revision and examination

1. What funcitonal significance is attributed to the radial and circular orientation of muscles of facial expression? Give examples.

2. Name the parts of the orbicularis oculi muscle. Where are their points of origin and insertion, and what functions do they have?

3. What are the functions of the occipital and frontal venters of the occipitofrontal muscle?

4. Which muscles raise the mandible?

5. Which muscles lower the mandible?

6. Where does the mandible displace during bilateral contraction of the lateral pterygoid muscles?

7. Where does it displace during unilateral contraction of the lateral pterygoid muscle?

8. Name the fatty tissue spaces of the head and say where they are situated.

MUSCLES AND FASCIAE OF THE NECK

Muscles of the neck are divided into groups according to their derivation (origin of development) and topography. According to derivation, there are muscles, which develop from the first (mandibular) and second (hyoid) visceral arches, which develop from the branchial arches and muscles and which derive from the ventral sections of myotomes.

Mesenchyme of the first visceral arch develops into the mylohyoid muscle and the anterior venter of the digastric muscle. Mesenchyme of the second visceral arch develops into the stylohyoid muscle, the posterior venter of the digastric muscle and the platysma (one of the facial expression muscles). Transformation of the branchial arches produces the sternocleidomastoid and trapezius muscles. Ventral sections of myotomes develop into the sternohyoid, thyrohyoid, sternothyroid and omohyoid muscles, as well as the anterior, middle and posterior scalene and the prevertebral muscles.

According to topography, there are superficial and deep muscles of the neck. The superficial group includes the platysma and sternocleidomastoid muscles, and two subgroups of muscles, which attach to the hyoid bone (Fig. 102 and 103). The suprahyoid group includes the mylohyoid, digastric, stylohyoid and geniohyoid muscles. The group of muscles situated below the hyoid bone (infrahyoid) includes the sternohyoid, sternothyroid, thyrohyoid and omohyoid muscles. The deep muscles of the neck are divided into the medial (prevertebral) and lateral groups. The medial group includes the longus colli and capitis muscles. The lateral group includes the anterior, middle and posterior scalene muscles.

SUPERFICIAL MUSCLES OF THE NECK

The platysma muscle (m. platýsma) is a very thin and flat muscle of facial expression, situated directly beneath the skin. It originates on the superficial lamina of the pectoral fascia, stretches upward covering the entire anterolateral surface of the neck. The platysma continues onto the face, inserting into the masseteric fascia and the depressor muscle of the lower lip.

F u n c t i o n: It tenses the skin of the neck, protecting superficial veins from collapsing, and pulls the angle of the mouth down.

I n n e r v a t i o n: facial nerve.

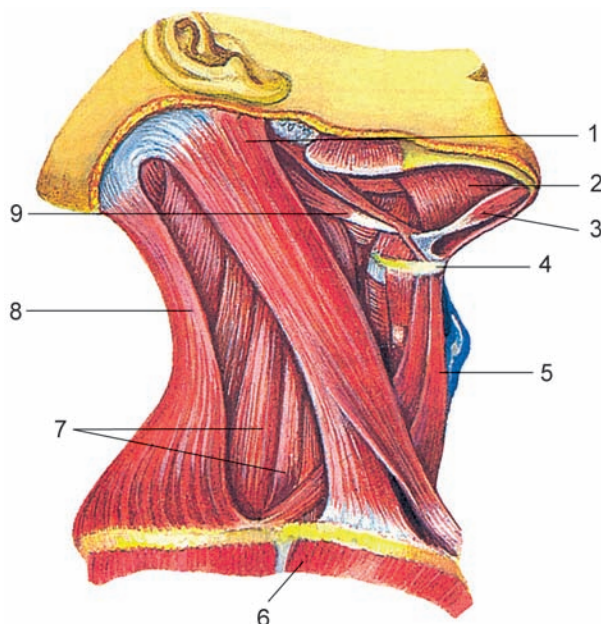B l o o d   s u p p l y: transverse cervical artery, facial artery.

Fig. 102. Muscles of neck. Right aspect.

1 — sternocleidomastoid; 2 — mylohyoid; 3 — digastric (anterior belly); 4 — hyoid bone; 5 — sternohyoid; 6 — omohyoid muscle; 7 — anterior and middle scaleni muscles; 8 — trapesius; 9 — digastric (posterior belly).

The sternocleidomastoid muscle (m. sternocleidomastoídeus) originates from the anterior surface of manubrium sterni and medial end of clavicle. It stretches upward and somewhat lateral and attaches on the mastoid process of temporal bone.

F u n c t i o n: during bilateral contraction it bends the head back; unilateral contraction bends the head to the corresponding side and turns the face toward the opposite side. When the head is fixed this muscle pulls up the thorax, contributing to inhaling.

I n n e r v a t i o n: accessory nerve.

B l o o d   s u p p l y: sternocleidomastoid branch (of the superior thyroid artery), occipital and superior thyroid arteries.

Muscles situated above the hyoid bone

The digastric muscle (m. digástricus) consists of anterior and posterior venters. The p o s t e r i o r   b e l l y (venter) arises in the mastoid process of the temporal bone, stretches downward and to the front, adjoining

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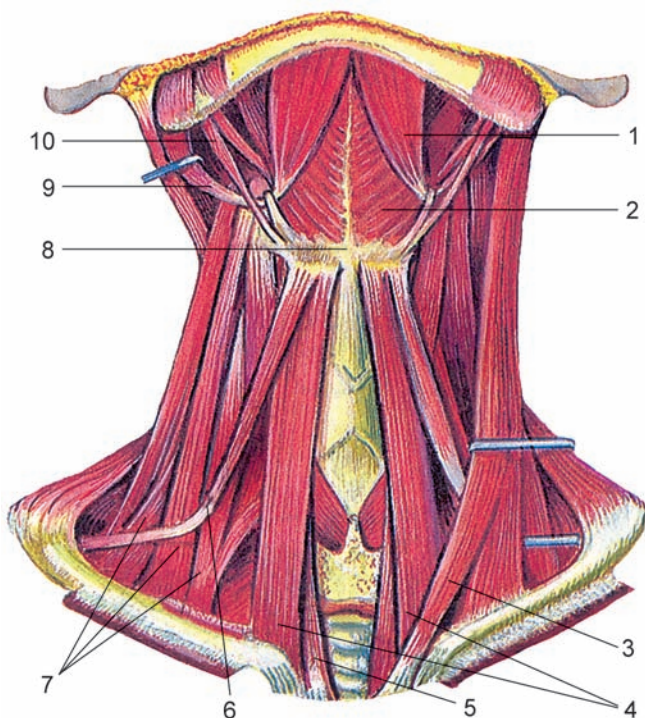
Fig. 103. Muscles of neck. Anterior aspect.

1 — digastric (anterior belly); 2 — mylohyoid; 3 — sternocleidomastoid; 4 — sternohyoid; 5 — sternothyroid; 6 — omohyoid; 7 — scalenes (anterior, middle, posterior); 8 — hyoid bone; 9 — digastricus; 10 — stylohyoid.

the posterior surface of the stylohyoid bone. It continues into the i n t e r - m e d i a t e   t e n d o n, which perforates the stylohyoid muscle and is inserted into the greater horn of the hyoid bone with a tendinous loop. The intermediate tendon continues into the a n t e r i o r   b e l l y, which stretches up and to the front to the digastric fossa of the mandible.

F u n c t i o n: During bilateral contraction this muscle pulls the hyoid bone upward and to the back. The anterior venters dislocate the hyoid bone up and forward. When the hyoid bone is fixed (during contraction of the infrahyoid muscles) this muscle lowers the mandible, thus opening the mouth.

I n n e r v a t i o n: posterior belly — facial nerve; anterior belly—mylohyoid nerve.

B l o o d   s u p p l y: mental, occipital and auricular arteries.

The stylohyoid muscle (m. stylohyoídeus) originates from the styloid process of the temporal bone, stretches forward and down and is inserted into the body of the hyoid bone.

Function: During unilateral contraction it pulls the hyoid bone backward and up, to the corresponding side. Bilateral contraction dislocated the hyoid bone up and to the back.

Innervation: facial nerve.

Blood supply: occipital and facial arteries, sublingual branch of the lingual artery.

The mylohyoid muscle (m. mylohyoídeus) is a broad flat muscle. It originates on the mylohyoid line of the mandible. The medial two thirds of its fascicles stretch toward the middle line, where they form the tendinous raphe. Its lateral fascicles insert on the body of the hyoid bone. The mylohyoid muscle forms the muscular base of the diaphragm of the mouth. At the top it adjoins to the sublingual gland and geniohyoid muscle. At the bottom it adjoins the anterior venter of the digastric muscle.

Function: When the mandible is fixed (the mouth is closed) this muscle raises the hyoid bone together with the larynx. When the hyoid bone is fixed it lowers the mandible.

Innervation: mylohyoid nerve (branch of the inferior alveolar nerve)

Blood supply: sublingual and mental arteries.

The geniohyoid muscle (m. geniohyoídeus) is situated on the superior surface of the mylohyoid muscle, at either side of the middle line. It originates from the mental spine and is inserted into the body of the hyoid bone.

Function: When the mandible is fixed it lifts the hyoid bone together with the larynx (during swallowing or speech). When the hyoid bone is fixed it lowers the mandible.

Innervation: hypoglossal nerve, muscular branch of the cervical plexus.

Blood supply: sublingual artery, mental artery.

Muscles situated below the hyoid bone

During contraction, these muscles fix the hyoid bone forming a support for the larynx and mandible.

The omohyoid muscle (m. omohyoídeus) originates with its inferior belly on the superior margin of the scapula. The inferior belly stretches obliquely upward and to the front, passing lateral of the scalene muscles. Below the posterior edge of the sternocleidomastoid muscle this venter continues into the intermediate tendon, which passes into the superior venter. The superior belly stretches upward and to the front, and is inserted into the hyoid bone.

F u n c t i o n: When the hyoid bone is fixed, bilateral contraction stretches the pretracheal lamina of the cervical fascia preventing the collapse of deep veins of the neck. When the scapula is fixed this muscle pulls the hyoid bone down and to the back. Unilateral contraction dislocates the hyoid bone down and backwards, and toward the corresponding side.

I n n e r v a t i o n: cervical ansa.

B l o o d s u p p l y: inferior thyroid and transverse cervical arteries.

The sternohyoid muscle (m. sternohyoídeus) originates on the posterior surface of manubrium sterni and sternal end of clavicle and is inserted into the hyoid bone.

I n n e r v a t i o n: cervical ansa.

B l o o d s u p p l y: inferior thyroid and transverse cervical arteries.

The sternothyroid muscle (m. sternothyroídeus) originates from the posterior surface of the manubrium sterni and the first costal cartilage. It stretches upward and is inserted into the oblique line of the thyroid cartilage.

F u n c t i o n: lowers the larynx.

I n n e r v a t i o n: cervical ansa.

B l o o d s u p p l y: inferior thyroid and transverse cervical arteries.

The thyrohyoid muscle (m. thyrohyoídeus) is, in a way, a continuation of the sternothyroid muscle. It originates from the oblique line of the thyroid cartilage and attaches the body and greater horn of the hyoid bone.

F u n c t i o n: Brings the hyoid bone closer to the larynx. When the hyoid bone is fixed it raises the larynx.

I n n e r v a t i o n: cervical ansa.

B l o o d s u p p l y: inferior thyroid and transverse cervical arteries.

DEEP MUSCLES OF THE NECK

The deep muscles of the neck are divided into a lateral and medial groups. The lateral group includes the anterior, middle and posterior scalene muscles. The medial group includes the longus colly and longus capitis muscles, rectus capitisanterior and rectus capitis lateralis muscles.

The anterior scalene muscle (m. scalénus antérior) originates from the transverse processes of C3 and C4 vertebrae. It stretches downward and is inserted into the tubercle of anterior scalene muscle of the first rib.

I n n e r v a t i o n: cervical plexus.

B l o o d s u p p l y: ascending cervical artery, inferior thyroid aretery.

The middle scalene muscle (m. scalénus médius) originates from the transverse processes of C2-C7 vertebrae. It stretches down and lateral

and is inserted into the upper edge of rib 2, behind the groove of the sub-clavian artery.

I n n e r v a t i o n: cervical plexux.

B l o o d s u p p l y: vertebral artery, deep cervical artery.

The posterior scalene muscle (m. scalénus postérior) originates from the posterior tubercles of transverse processes of C4-C6 vertebrae, and is inserted into the upper edge of rib 2.

I n n e r v a t i o n: cervical plexus.

B l o o d s u p p l y: transverse cervical artery, deep cervical artery.

Function of the scalene muscles: When the cervical section of the spine is fixed, these muscles raise ribs 1 and 2 lifting the thorax. When the thorax is fixed, they bend the cervical spine forward and toward the corresponding side.

The rectus capitis anterior muscle (m. réctus cápitis antérior) originates from anterior surface of lateral mass of the atlas and fixes to the basilar part of occipital bone. It bends head forward.

I n n e r v a t i o n: cervical plexus.

B l o o d s u p p l y: vertebral artery, ascending pharyngeal artery.

The rectus capitis lateralis muscle (m. réctus cápitis laterális) originates from the transverse process of atlas and fixes to the inferior surface of jugular process of occipital bone.

It bends head sideways.

I n n e r v a t i o n: cervical plexus.

B l o o d s u p p l y: occipital artery, vertebral artery.

Muscles of the neck are demonstrated in the table 13.

Table 13. Muscles of the neck.

Muscle	Origin	Insertion	Action	Innervation
Superficial muscles of the neck				
Platysma	Thoracic fascia and skin of upper part of the chest (level of rib 2)	Temporal fascia, inferior edge of mandible and angle of mouth	Draws angle of mouth downward; pulls skin of the neck outward, preventing compression of subcutaneous veins	Facial nerve
Sternocleido-mastoid	Manubrium of sternum and medial third of clavicle	Mastoid process of temporal bone and superior nuchal line	Unilateral contraction bend head to same side and turns face to opposite side; bilateral contraction hyperextends the neck	Accessory nerve
Trapezius	see table 8			

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Suprahyoid muscles				
Digastric	Mastoid notch (posterior venter)	Digastric fossa of mandible. Both venters are attached to the hyoid bone	Draws the hyoid bone upward. When the latter is fixated, it lowers the mandible	Anterior venter—trigeminal nerve; posterior venter—facial nerve
Stylohyoid	Styloid process of temporal bone	Body of hyoid bone	Pulls hyoid bone upward	Facial nerve
Mylohyoid	Internal surface of body of mandible	Left and right muscles accrete with each other, forming the diaphragm of mouth	Pulls hyoid bone upward	Mylohyoid nerve (from trigeminal nerve)
Geniohyoid	Mental spine of mandible	Body of hyoid bone	Pulls hyoid bone upward; when the latter is fixated, it lowers the mandible	Muscular branches of cervical plexus
Infrahyoid muscles				
Sternohyoid	Posterior surface of manubrium of sternum and sternal end of clavicle	Body of hyoid bone	Pulls hyoid bone downward	Ansa cervicalis
Sternothyroid	Posterior surface of manubrium of sternum and first costal cartilage	Thyroid cartilage	Pulls larynx downward	Same as above
Omohyoid	Superior border of scapula	Body of hyoid bone	Pulls hyoid bone downward and stretches the cervical fascia	Same as above
Thyrohyoid	Oblique line of thyroid cartilage	Body and greater horn of hyoid bone	When the hyoid bone is fixated it pulls the larynx upward	Same as above
Deep muscles of the neck Lateral group				
Anterior scalene	Transverse processes of C3-C7 vertebrae	Tubercle of anterior scalene on rib1	All muscles of the lateral group pull upward ribs 1 and 2. When the ribs are fixated they flex the cervical spine	Muscular branches of cervical and brachial plexuses
Middle scalene	Transverse processes of C2-C7 vertebrae	Rib 1, behind the groove of subclavian artery		

Posterior scalene	Transverse processes of C4-C6 vertebrae	Upper edge of rib2		
Prevertebral (medial) group				
Longus colli	Anterior surfaces of bodies and transverse processes of C3-C7 and T1-T3 vertebrae	Bodies and transverse processes of C1-C5 vertebrae and anterior tubercle of atlas	Flexion of cervical spine (during unilateral contraction — bending to same side)	Muscular branches of cervical plexus
Longus capitis	Transverse processes of C3-C6 vertebrae	Underside of basilar part of occipital bone	Bends head forward	Same as above
Rectus capitis anterior muscle	Anterior surface of lateral mass of atlas	Underside of basilar part of occipital bone	Same as above	Same as above
Rectus capitis lateralis muscle	Transverse process of atlas	Inferior surface of jugular process of occipital bone	Bends head sideways	Same as above

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE NECK

The platysma muscle, like the other facial expression muscles, is situated beneath the skin and is covered only by its own proper fascia.

Corresponding to the three groups of muscles of the neck (superficial suprahyoid and infrahyoid), which have different derivations and anatomic locations, the c e r v i c a l f a s c i a has three layers or lamina (three cervical fasciae) (Fig. 104).

The s u p e r f i c i a l l a m i n a is attached to the hyoid bone; it covers from the front the infrahyoid and suprahyoid muscles. This lamina accretes with the connective tissue capsule of the sublingual gland, the masseteric fascia and the capsule of the parotid gland. Towards the posterior regions of the neck it accretes with the nuchal ligament. At the top it attaches to the external occipital protuberance and the superior nuchal line, and at the bottom it continues into the fsuperficial fascia of back.

The p r e t r a c h e a l l a m i n a accretes on the right and left sides with the connective tissue sheath of the neurovascular bundle (carotid artery, internal jugular vein and vagus nerve) and with the superficial lamina. Behind the pretracheal lamina lie the larynx, the thyroid gland and the upper section of the trachea. In front of it is only the superficial lamina of the cervical fascia and the platysma, which separate the skin and the inter-
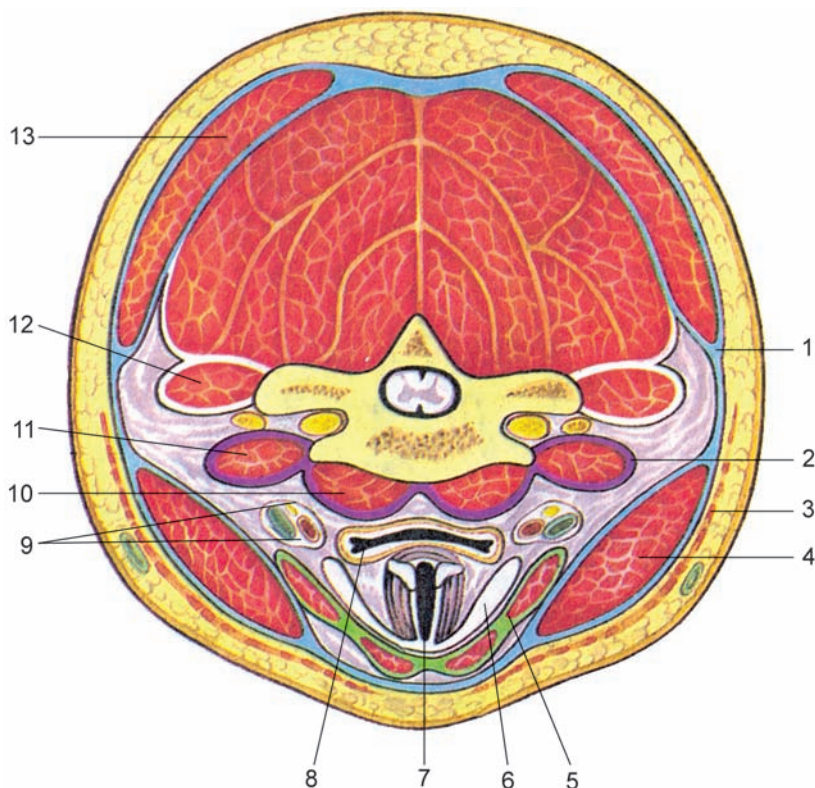
Fig. 104. Positioning of plates of cervical fascia (transverse section at a level of larynx). 1 — superficial layer; 2 — prevertebral layer; 3 — platysma; 4 — sternocleidomastoid; 5 — pretracheal layer; 6 — thyroid cartilage; 7 — rima vocalis; 8 — oesophagus; 9 — carotid sheath; 10 — longus colli; 11 — scalenus anterior; 12 — scalenus posterior; 13 — trapesius.

nal organs of the neck. The pretracheal lamina of the cervical fascia has the shape of a trapezoid, bordered by its points of attachment to lateral anatomical structures of the neck. Due to its anatomic and topographic characteristics this lamina is also called the scapuloclavicular aponeurosis. The pretracheal lamina reminds a sail, especially when it is stretched by contraction of omohyoid muscles, which eases the outflow of blood from the head. Between the superficial and pretracheal laminae, above the jugular notch, is the s u p r a s t e r n a l i n t e r f a s c i a l f a t t y t i s s u e s p a c e, which contains the jugular venous arch, which connects the right and left superficial veins. Behind the right and left sternocleidomastoid muscles this fatty tissue space has protrusions, which extend to the lateral edges of these muscles.

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Between the internal organs of the neck (thyroid gland, larynx and trachea) and the pretracheal lamina is a p r e t r a c h e a l   f a t t y   t i s s u e   s p a c e. Along the anterior surface of trachea this space communicates with the anterior mediastinum.

The p r e v e r t e b r a l (deep) l a m i n a, which is situated behind the larynx and esophagus, covers the scalene muscles, long muscles of the head and neck, and anterior and lateral rectus muscles of the head. At the top this lamina attaches to the outside of the skull base, behind the pharyngeal tubercle; at the sides it attaches to trasverse processes of cervical vertebrae and forms fascial sheaths (cases) for the scalene muscles. At the bottom the prevertebral lamina attaches to ribs 1 and 2 and continues into the endothoracic fascia. Between this lamina and the pharynx and esophagus is a p r e v e r t e b r a l   f a t t y   t i s s u e   s p a c e, which continues along the esophagus into the posterior mediastinum.

The interfascial spaces, filled by loose fibrous connective tissue, can spread inflammatory processes not only within the neck, but also into the anterior and posterior mediastina.

In the posterior regions of the neck, between muscles of the occipital group are the laminae of the n u c h a l   f a s c i a (fáscia núchae), which forms the fascial sheath of these muscles. At the bottom this fascia continues into the thoracolumbar fascia.

TRIANGLES OF THE NECK

According to the surface topographical relief of the neck, it is divided into the anterior, sternocleidomastoid (right and left) and lateral (right and left) regions.

The anterior region, or **anterior cervical triangle (trigónum cervicále antérius)**, is bordered at the sides by the sternocleidomastoid muscles. The base of the triangle is formed by the mandible, and the apex reaches the jugular notch of the manubrium sterni. This region, in turn, contains the medial cervical triangle, bordered by the middle line, the mandible and the edge of the sternocleidomastoid. The anterior region is also subdivided into a s u p r a h y o i d (régio s u p r a h y o í d e a) and i n f r a h y o i d (régio i n f r a h y o í d e a) r e g i o n s. The infrahyoid region contains the carotid and muscular (omotracheal) triangles. The c a r o t i d   t r i a n g l e (trigónum caróticum) is bordered by the posterior venter of the digastric muscle, the anterior edge of the sternocleidomastoid muscle and the superior venter of the omohyoid muscle. Beneath the superficial lamina of the cervical fascia this triangle contains the cervical branch of facial nerve, superior branch of the transverse cervical nerve

and the anterior jugular vein. Beneath them, encased in a connective tissue sheath lie the common carotid artery, internal jugular vein and, behind them, the vagus nerve. Also in this region lie the deep lateral cervical lymph nodes. Within the carotid triangle, at the level of the hyoid bone, the common carotid artery divides into the external and internal carotid arteries. To the front of the sheath of the neurovascular bundle lies the superior root of the hypoglossal nerve. Somewhat deeper and lower than this root lies the pharyngeal nerve (branch of the vagus), and deeper, on the prevertebral lamina of the cervical fascia, lied the sympathetic trunk.

The omotracheal triangle (trigónum omotracheále) is bordered by the anterior edge of the sternocleidomastoid muscle, the superior venter of the omohyoid muscle and the middle line.

Within this triangle, above the jugular notch, the trachea is covered only by the skin and the superficial and pretracheal laminae of the cervical fascia. About 1 cm away from the middle line lies the anterior jugular vein, which extends into the interfascial fatty tissue space.

The suprahyoid region is divided into the unpaired submental and paired submandibular and lingual triangles.

The submental triangle (trigónum submentále) is bordered by the anterior ventricles of the digastric muscles. The base of the triangle is formed by the hyoid bone and its floor is formed by the right and left mylohyoid muscles. This triangle contains the submental lymph nodes.

The submandibular triangle (trigónum submandibuláre) is bordered by the body of the mandible and the anterior and posterior venters of the digastric muscle. This triangle confines the homonymous salivary gland. It also contains the cervical branch of the facial nerve and branches of the transverse nerve of the neck. In the superficial part of the triangle lie the facial artery and vein, and behind the submandibular gland lies the retromandibular vein. Within the triangle also lie the homonymous lymph nodes.

The lingual triangle (Pirogoff's triangle, trigónum linguále) is situated within the submandibular triangle. It is bordered by the posterior edge of the mylohyoid muscle, the posterior venter of the digastric muscle and the sublingual nerve.

The l a t e r a l r e g i o n o f t h e n e c k is divided into the omoclavicular and omotrapezius triangles. The o m o c l a v i c u l a r t r i a n g l e (trigónum omoclaviculáre) is bordered by the clavicle, the inferior venter of the omohyoid muscle and the posterior edge of the sternocleidomastoid muscle. This triangle contains the end part of the subclavian artery, nerves of the brachial plexus, suprascapular artery and superficial cervical artery. To the front of the subclavian artery and the anterior scalene muscle (in the prescalene space) lies the subclavian vein. This vein is tightly
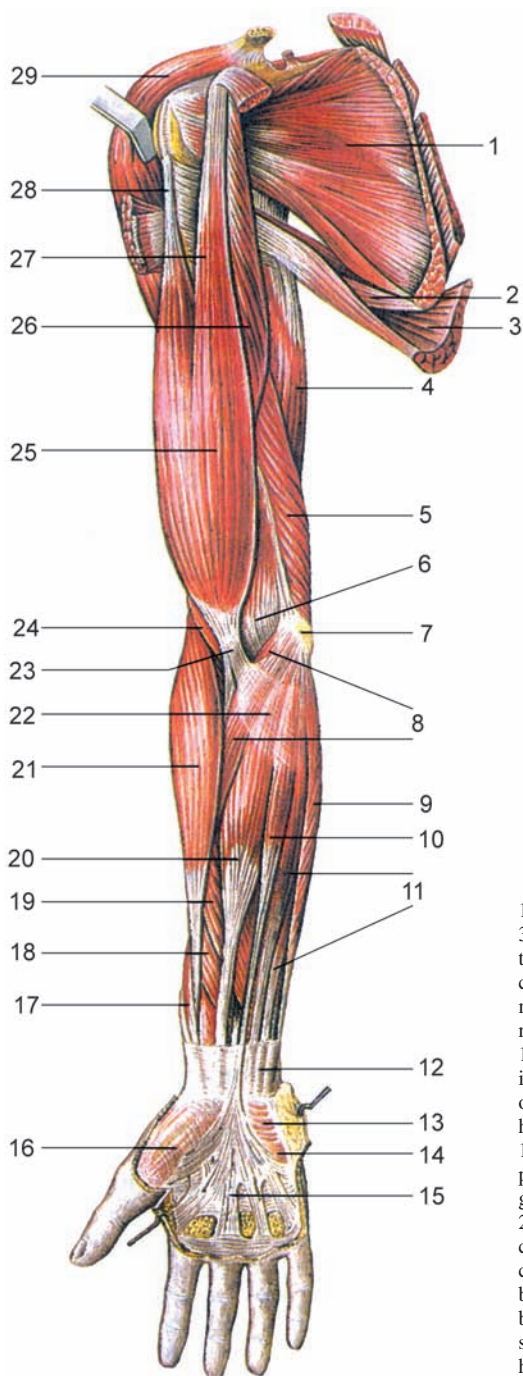
Fig. 105. Muscles of upper limb. Anterior aspect.

1 — subscapularis; 2 — teres major; 3 — latissimus dorsi; 4 — long head of triceps brachii; 5 — medial head of triceps brachii; 6 — cubital fossa; 7 — medial epicondyle of humerus; 8 — pronator teres; 9 — flexor carpi ulnaris; 10 — palmaris longus; 11 — flexor digitorum superficialis; 12 — part of fascia of forearm; 13 — palmaris breve; 14 — hypothenar; 15 — palmar aponeurosis; 16 — thenar; 17 — tendo of abductor pollicis longus; 18 — flexor pollicis longus; 19 — flexor digitorum superficiale; 20 — flexor carpi radialis; 21 — brachioradialis; 22 — aponeurosis of biceps brachii; 23 — tendon of biceps brachii; 24 — brachialis; 25 — biceps brachii; 26 — coracobrachialis; 27 — short head of biceps brachii; 28 — long head of biceps brachii; 29 — deltoid.

accreted with the fascia of the subclavian muscle and laminae of the cervical fascia.

The omotrapezius triangle (trigónum omotrapezoídeum) is bordered by the edge of the trapezius muscle, the interior venter of the omohyoid muscle and posterior edge of the sternocleidomastoid muscle. It contains the accessory nerve. Between the scalene muscles lie the cervical and brachial plexuses.

Questions for revision and examination

1. What groups are muscle of the neck divided into according to the derivation and location?

2. How many laminae does the cervical fascia have and for which muscles does it form sheaths?

3. Name the triangles (and their borders) of the anterior and lateral regions of the neck.

MUSCLES AND FASCIAE OF THE UPPER EXTREMITY

As an instrument of work, the arm is capable of a great variety of movements. The presence of many long and short muscles and the structural features of the shoulder and elbow joints enable the upper extremity to perform delicate, precise movements within wide amplitude.

According to the points of origin and insertion and to the joints, which are moved, the muscles of the upper extremity are divided into the muscles of the upper limb (shoulder) girdle and muscles of the free upper extremity.

MUSCLES OF THE SHOULDER GIRDLE

The muscles of the shoulder girdle originate from the clavicle and the scapula and are inserted into the humerus. These muscles cause movement in the glenohumeral, or shoulder, joint. The most superficial of these is the deltoid muscle. Deeper, beneath the deltoid muscle, lie the supraspinous and infraspinous muscles, teres major and teres minor muscles and the subscapularis muscle (Fig. 105, 106).

The deltoid muscle (m. deltoídeus) is situated directly below the skin and covers the shoulder joints from the front, back, the side and the top, forming the characteristic curve of the shoulder. It originates on the anterior edge of lateral end of clavicle, the acromion, the scapular spine and adjoining part of the infraspinous fascia. Its fascicles converge on the lateral surface of the humerus and are inserted into the deltoid tuberosity. Beneath the deltoid muscle, between the deep lamina of its fascia and the greater tubercle of the humerus, is the synovial subdeltoid bursa.
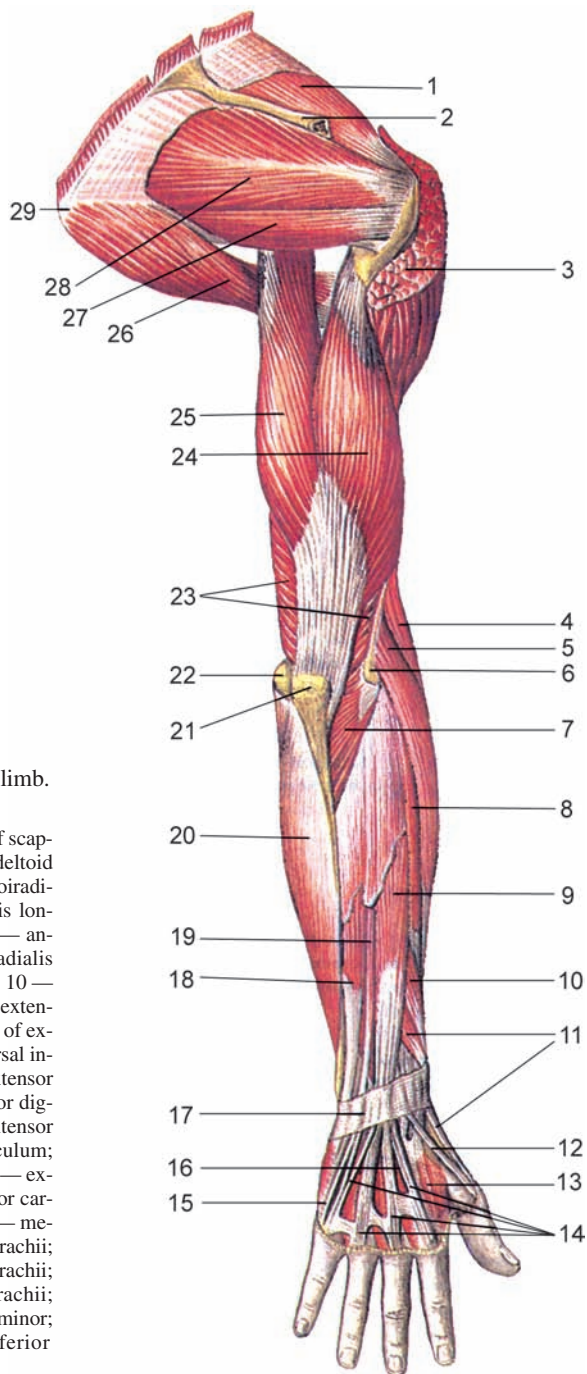
Fig. 106. Muscles of upper limb. Posterior aspect.

1 — supraspinatus; 2 — spine of scapula (partially removed); 3 — deltoid (partially removed); 4 — brachoiradialis; 5 — extensor carpi radialis longus; 6 — lateral epicondyle; 7 — anconeus; 8 — extensor carpi radialis brevis; 9 — extensor digitorum; 10 — abductor pollicis longus; 11 — extensor pollicis brevis; 12 — tendon of extensor pollicis longus; 13 — dorsal interosseal 1st; 14 — tendon of extensor digitorum; 15 — tendon extensor digiti minimi; 16 — tendon of extensor indicis; 17 — extensor retinaculum; 18 — extensor carpi ulnaris; 19 — extensor digiti minimi; 20 — flexor carpi ulnaris; 21 — olecranon; 22 — medial epicondyle; 23 — triceps brachii; 24 — lateral head of triceps brachii; 25 — long head of triceps brachii; 26 — teres major; 27 — teres minor; 28 — infraspinatus; 29 — inferior angle of scapula.

F u n c t i o n: During contraction of the entire muscle the arm is abducted approximately 70 percent of possible amplitude. During contraction of its anterior (c l a v i c u l a r) f a s c i c l e s the arm is partially flexed and pronated. If the arm is raised the clavicular part of the muscle lowers it. The posterior (s p i n a l) f a s c i c l e s extends, supinates and somewhat raise the arm. The middle (a c r o m i a l) p a r t of the muscle abducts the arm.

I n n e r v a t i o n: axillary nerve.

B l o o d   s u p p l y: posterior circumflex humeral artery, thoracoacromial artery.

The supraspinatus muscle (m. supraspinátus) originates from the posterior surface of the scapula, above its spine, and on the supraspinous fascia. Its fascicles stretch laterally and are inserted into the lower part of the greater tubercle of the humerus. Part of its fascicles weaves into the capsule of the shoulder joint.

F u n c t i o n: Abducts the arm and pulls the articular capsule outward, preventing it from being jammed.

I n n e r v a t i o n: suprascapular nerve.

B l o o d   s u p p l y: suprascapular artery, circumflex scapular artery.

The infraspinatus muscle (m. infraspinátus) originates from the posterior surface of the scapula (beneath the spine) and from the infraspinous fascia. It stretches laterally, behind the shoulder joint, and is inserted into the greater tubercle of the humerus, below the tendon of the suprascapular muscle. Part of the fascicles of its tendon weaves into the articular capsule.

F u n c t i o n: It supinates the arm and stretches the capsule of the shoulder joint.

I n n e r v a t i o n: suprascapular nerve.

B l o o d   s u p p l y: suprascapular artery, circumflex scapular artery.

The teres minor muscle (m. téres mínor) originates from the lateral margin of scapula and from the infraspinous fascia. It is inserted into the greater tubercle of the humerus, below the tendon of the infraspinous muscle. The teres minor muscle lies adjacent to the infraspinous muscle and is covered in the back by the scapular part of deltoid muscle.

F u n c t i o n: It supinates the arm and pulls the capsule of the shoulder joint outward.

I n n e r v a t i o n: axillary nerve.

B l o o d   s u p p l y: circumflex scapular artery

The teres major muscle (m. téres májor) originates from the lower part of the lateral margin of the scapula and from the infraspinous fascia. Its muscle fascicles stretch along the lateral margin of the scapula, crossing the humerus on the medial side, below its surgical neck. It is inserted

into the crest of the lesser tubercle of the humerus, more distal and to the back than the latissimus dorsi muscle.

F u n c t i o n: When the scapula is fixed it extends the shoulder and pronates it. It adducts the arm. When the humerus is fixed it pulls the inferior angle of the scapula forward and to the side.

I n n e r v a t i o n: subscapular nerve.

B l o o d   s u p p l y: subscapular artery.

The subscapularis muscle (m. subscapuláris) is strong and thick, and almost triangular. It originates from the entire surface of the subscapular fossa and the lateral margin of the scapula. It is inserted into the lesser tubercle of thehumerus and its crest. Beneath the tendon of this muscle there is a subtendinous bursa of subscapular muscle, which often communicates with the articular cavity of the shoulder joint.

F u n c t i o n: It pronates the arm and adducts it to the body.

I n n e r v a t i o n: subscapular nerve.

B l o o d   s u p p l y: subscapular artery.

MUSCLES OF THE FREE UPPER EXTREMITY

According to their topography and anatomic structure the muscles of the arm are divided into an anterior (flexor muscles) and a posterior (extensor muscles) groups. The anterior group includes the coracobrachialis, biceps brachii and brachial muscles. The posterior group consists of the triceps brachii and anconeus muscles.

Anterior muscles of the arm

The coracobrachialis muscle (m. coracobrachiális) originates from the apex of the coracoid process and is inserted into the humerus, below the crest of the lesser tubercle, at the same level with the deltoid muscle. Part of its fascicles weaves into the medial intermuscular septum of the arm.

F u n c t i o n: It flexes the arm and adducts it to the body. When the arm is pronated this muscle supinates it. When the arm is fixed it pulls the scapula forward and down.

I n n e r v a t i o n: musculocutaneous nerve.

B l o o d   s u p p l y: posterior and anterior circumflex humeral arteries.

The biceps brachii muscle (m. bíceps bráchii) has a long and a short heads of origin. The l o n g   h e a d originates from the supraglenoid tubercle of scapula. Its tendon stretches through the articular cavity of the shoulder joint and passes along the intertubercular groove. The s h o r t h e a d originates from the coracoid process of the scapula. The two heads

unite at midlevel of humerus into a common venter, which continues into a tendon. This tendon is inserted into the tuberosity of the radius. Between the anteromedial surface of the tendon and the antebrachial fascia is a fibrous plate called the b i c i p i t a l a p o n e u r o s i s (Pirogoff's fascia)

F u n c t i o n: It flexes the arm in the shoulder joint and the forearm in the elbow joint. When the forearm is pronated this muscle supinates it.

I n n e r v a t i o n: musculocutaneous nerve.

B l o o d s u p p l y: brachial artery, superior and inferior collateral ulnar arteries, radial recurrent artery.

The brachialis muscle (m. brachiális) originates from the lower two thirds of the body of the humerus, between the deltoid tuberosity and articular capsule of the elbow joint, and from the medial and lateral intermuscular septa of the arm. It attaches to the tuberosity of the ulna. Some of its fascicles weave into the capsule of the elbow joint.

F u n c t i o n: It flexes the forearm in the elbow joint.

I n n e r v a t i o n: musculocutaneous nerve.

B l o o d s u p p l y: superior and inferior collateral ulnar arteries, brachial artery, radial recurrent artery.

Posterior muscles of the arm

The triceps brachii muscle (m. tríceps bráchii) covers the entire posterior surface of the humerus, forming the surface contours of the arm. It has a long, a medial (deep) and a lateral heads of origin. The l o n g h e a d originates on the infraglenoid tubercle of the scapula, and stretches downward between the teres major and teres minor muscles. Approximately at midlevel of the humerus it unites with the lateral and medial heads. The l a t e r a l h e a d originates from the lateral surface of thehumerus, between the insertion of the teres minor muscle and the radial groove, and on the back of the lateral intermuscular septum. This head stretches downward and medial, by covering the radial groove with its vessels and nerves. The m e d i a l h e a d of triceps originates from the posterior surface of humerus between the place of insertion of the teres major muscle and the olecranon fossa, and from the medial and lateral intermuscular septa, below the radial groove. The common venter of the triceps continues into a broad flat tendon, which is inserted into the olecranon process of ulna. Part of its fascicles weaves into the capsule of the elbow joint and the antebrachial fascia.

F u n c t i o n: extends the forearm in the elbow joint. The long head extends and adducts the arm in the shoulder joint.
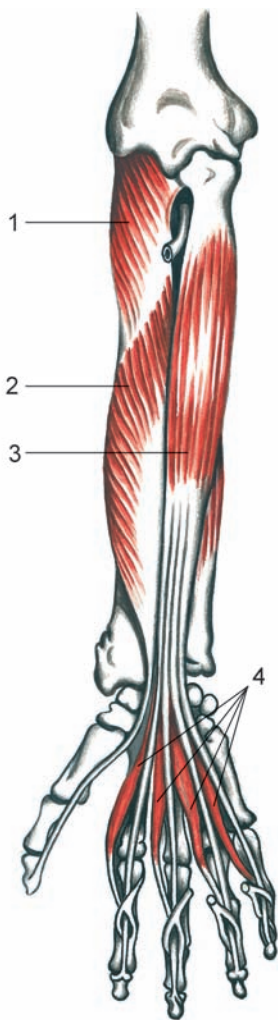
I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: posterior circumflex humeral artery, deep brachial artery, superior and inferior ulnar collateral arteries.

The anconeus muscle (m. ancóneus) is a small triangular muscle. It originates from the posterior surface of the lateral epicondyle of the humerus, and is inserted into the lateral surface of the olecranon process, the posterior surface of the ulna and the antebrachial fascia.

F u n c t i o n: It participates in extension of the forearm.

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: recurrent interosseous artery.

The muscles of the forearm are divided into an anterior (flexors of the wrist and fingers) and posterior (extensors) groups. The muscles of the anterior group (7 flexors and 2 pronators) are situated in 4 layers (Fig. 107). The muscles of the posterior group (9 extensors and one supinator) are situated in two layers.

First (superficial) layer of the anterior muscles of the forearm

The brachioradialis muscle (m. brachioradiális) originates from the lateral supracondylar crest of humerus and the lateral intermuscular septum. It borders the olecranon fossa from the lateral side. At midlevel of the forearm its venter continues into a narrow flat tendon. This tendon passes underneath tendons of the long abductor and short extensor muscles of the thumb, and is inserted into the lateral surface of the distal end of radius.

F u n c t i o n: It flexes the forearm in the elbow joint; sets the hand in an intermediate position between pronation and supination, turning the radius outward.

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: radial artery, radial collateral artery, recurrent radial artery.

The pronator teres muscle (m. pronátor téres) is a short muscle with unequally sized heads. The humeral head originates from the medial epicondyle of the humerus, antebrachial fascia and medial intermuscular septum of the forearm. The lesser head has a deeper origin on the coronoid process of the ulna. This muscle stretches downward and laterally, bordering the olecranon fossa from the lateral side. Its tendon is inserted into the lateral surface of the radius, approximately at its middle.

F u n c t i o n: This muscle pronates the forearm together with the hand, acting upon the radioulnar joints. It takes part in flexion of the forearm.

I n n e r v a t i o n: median nerve.

B l o o d   s u p p l y: brachial, ulnar and radial arteries.

The flexor carpi radialis muscle (m. fléxor cárpi radiális) originates on the medial epicondyle of humerus and the fascia and medial intermuscular septum of the arm. Approximately at the middle of the forearm it continues into a long narrow tendon, which passes through the carpal tunnel and is inserted into the base of the second metacarpal bone.

F u n c t i o n: It flexes the wrist in the radiocarpal joint. When contracting simultaneously with the radial extensor of the wrist, it abducts the hand.

I n n e r v a t i o n: median nerve.

B l o o d   s u p p l y: brachial, ulnar and radial arteries.

The palmaris longus muscle (m. palmáris lóngus) is a thin fusiform muscle. It originates on the medial epicondyle of humerus, antebrachial fascia and upper part of its medial intermuscular septum. Its long thin tendon passes through the carpal tunnel and is inserted into the palmar aponeurosis. This muscle is sometimes absent.

F u n c t i o n: It stretches the palmar aponeurosis and participates in flexion of the hand in the radiocarpal joint.

I n n e r v a t i o n: median nerve.

B l o o d   s u p p l y: radial artery.

The flexor carpi ulnaris muscle (m. fléxor cárpi ulnáris) has a humeral and an ulnar heads of origin. The h u m e r a l   h e a d originates on the medial epicondyle and medial intermuscular septum of the humerus.

The u l n a r h e a d originates from the deep lamina of the antebrachial fascia, medial edge of olecranon process and posterior margin of the ulna. On the proximal part of the forearm both heads continue into a common venter. The muscle stretches along the medial edge of the forearm and is inserted with a long tendon into the pisiform bone. Part of its fascicles forms the pisiform-hamate and pisiform-metacarpal ligaments.

F u n c t i o n: Flexion of the forearm. When contracting together with the ulnar extensor of the wrist, it adducts the hand.

I n n e r v a t i o n: the ulnar nerve.

B l o o d s u p p l y: superior and inferior ulnar collateral arteries, ulnar artery.

Second layer of the anterior muscles of the forearm

The flexor digitorum superficialis muscle (m. fléxor digitórum superficiális) has a h u m e r o u l n a r and r a d i a l h e a d s, which are connected by a tendinous lamina. The humeroulnar head originates from the medial epicondyle of the humerus, antebrachial fascia, ulnar collateral ligament and medial edge of the coronoid process of the ulna. The radial head originates from the proximal two thirds of anterior edge of the radius. They form a common venter on the proximal end of the forearm. Approximately at the middle of the forearm this venter is divided into four parts, which continue into separate tendons. These tendons pass through the carpal tunnel and are inserted into palmar surfaces of the bases of the middle phalanges (fingers II–V). At midlevel of the proximal phalanges each of these tendons splits into two peduncles, beneath which pass the tendons of the deep flexor of the fingers.

F u n c t i o n: This muscle flexes the middle phalanges, thus bending the fingers, and takes part in flexion of the wrist.

I n n e r v a t i o n: median nerve.

B l o o d s u p p l y: radial and ulnar arteries.

Third layer of anterior muscles of the forearm

The flexor digitorum profundus muscle (m. fléxor digitórum profúndus) originates from the front proximal two thirds of the interosseous membrane of the forearm. Its tendons stretch together with tendons of the flexor digitorum superficialis through the carpal tunnel, then pass between the peduncles of the later and is inserted into the base of distal phalanges.

F u n c t i o n: It flexes the distal phalanges of the fingers II-V and participates in flexion of the wrist.

I n n e r v a t i o n: median nerve, ulnar nerve.

B l o o d s u p p l y: ulnar and radial arteries.

The flexor pollicis longus muscle (m. fléxor póllicis lóngus) originates from the upper anterior surface of the radius and interosseous membrane of the forearm. Its tendon passes through the lateral part of the carpal tunnel and along the palm, between the two heads of the short flexor of thethumb. It attaches on the base of the distal phalanx of the thumb.

F u n c t i o n: It flexes the distal phalanx of the thumb, thus bending it, and participates in flexion of the wrist.

I n n e r v a t i o n: median nerve.

B l o o d s u p p l y: anterior interosseous artery.

Fourth (deep) layer of the anterior muscles of the forearm

The pronator quadratus muscle (m. pronátor quadrátus) is a flat muscle, situated on the distal end of the forearm. It originates on the anterior edge and anterior lower third of the body of the ulna, stretches across and is inserted into the anterior lower third of the radius.

F u n c t i o n: This muscle pronates the forearm.

I n n e r v a t i o n: median nerve.

B l o o d s u p p l y: anterior interosseous artery.

Posterior muscles of the forearm

Muscles of the posterior surface of the forearm are situated in two layers: superficial and deep. The superficial layer includes the extensor carpi radialis longus muscle, extensor carpi radialis brevis muscle, extensor digitorum, extensor digiti minimi and extensor carpi ulnaris. The deep layer includes the supinator, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, extensor indicis (Fig. 108).

Superficial layer of the posterior muscles of the forearm

The extensor carpi radialis longus muscle (m. exténsor carpi radiális lóngus) originates on the lateral intermuscular septum of the arm and lateral epicondyle of the humerus. Its beginning part lies adjacent to the lateral side of the elbow joint. On the forearm this muscle lies to the front of the extensor carpi radialis brevis and behind the brachioradial muscle. At midlevel of the forearm, its venter continues into a flat tendon, which
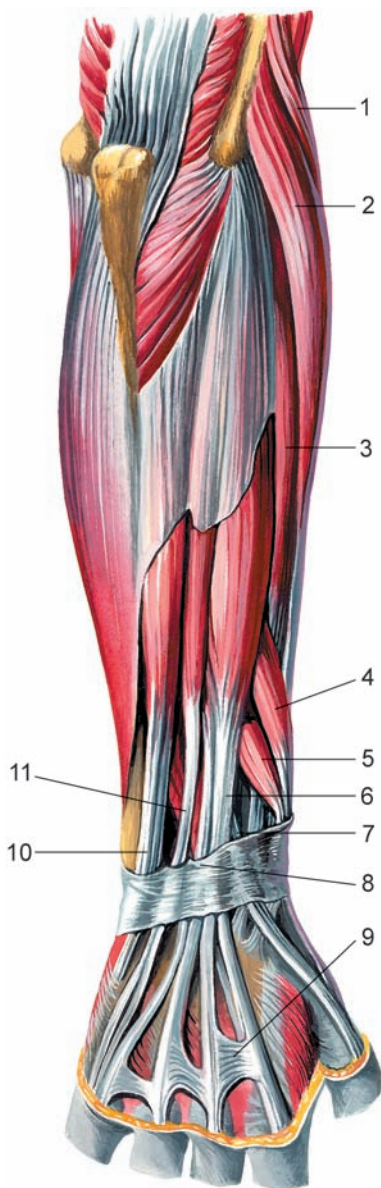
passes underneath the extensor retinaculum and is inserted into the base of the second metacarpal bone.

F u n c t i o n: It extends the wrist. When contracting simultaneously with the extensor carpi radialis brevis and the flexor carpi radialis, it abducts the wrist in the radiocarpal joint.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: collateral radial, recurrent radial and radial arteries.

The extensor carpi radialis brevis (m. exténsor cárpi radiális brévis) originates on the lateral epicondyle of humerus, the radial collateral ligament and the antebrachial fascia. It is inserted into the dorsal surface of the base of the third metacarpal bone.

F u n c t i o n: It extends the wrist. When contracting simultaneously with the extensor carpi radialis longus and the flexor carpi radialis, it abducts the wrist in the radiocarpal joint.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: collateral radial, recurrent radial and radial arteries.

The extensor digitorum muscle (m. exténsor digitórum) is situated medial of the radial extensors. It originates from the lateral epicondyle and from the antebrachial fascia. At the level of the radiocarpal joint it is divided into four tendons, which pass underneath the extensor retinaculum and is inserted into the bases of middle phalanges and on the distal

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phalanges. At the level of the heads of the metacarpal bones these tendons are connected by tendinous intersections.

F u n c t i o n: This muscle extends fingers II–V and participates in extension of the wrist in the radiocarpal joint.

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: posterior interosseous artery.

The extensor digiti minimi muscle (m. exténsor dígiti mínimi) has a common origin with the extensor of the fingers. Its long thin tendon passes under the extensor retinaculum, in its medial section. It is inserted into the dorsal surface of the bases of middle and distal phalanges of the little finger.

F u n c t i o n: Extends the little finger; participates in extending the wrist in the radiocarpal joint.

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: posterior interosseous artery.

The extensor carpi ulnaris (m. exténsor cárpi ulnáris) originates on the lateral epicondyle of humerus, the posterior surface of ulna, the capsule of the elbow joint and the antebrachial fascia. It is inserted into the dorsal surface of the base of the fifth metacarpal bone.

F u n c t i o n: It extends the wrist. When contracting together with the flexor carpi ulnaris it adducts the wrist in the radiocarpal joint.

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: posterior interosseous artery.

Deep layer of the posterior muscles of the forearm

The supinator muscle (m. supinátor) is almost completely covered by superficial muscles. It originates from the lateral epicondyle of the humerus, the radial collateral ligament, the annular ligament of the radius and on the supinator crest of the ulna. This muscle stretches obliquely laterally and is inserted into the lateral surface of upper third of the radial bone.

F u n c t i o n: It supinates the radius (together with the hand).

I n n e r v a t i o n: radial nerve.

B l o o d   s u p p l y: radial recurrent, recurrent interosseous and radial arteries.

The abductor pollicis longus muscle (m. abductor pollicis longus) originates on the posterior surfaces of the ulna and radius and the interosseous membrane of the forearm. It stretches downwards and laterally and curves about the radial bone and the tendons of the extensors carpi radialis. Its tendon, together with the tendon of the abductor pollicis longus, passes underneath the lateral part of the extensor retinaculum and is inserted into the base of the first metacarpal bone.

F u n c t i o n: Abduction of the thumb.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: posterior interosseous artery, radial artery.

The extensor pollicis brevis muscle (m. exténsor póllicis brevis) originates on the posterior surface of radius and the interosseous membrane of forearm. Its tendon passes through a common synovial sheath with the abductor pollicis longus and is inserted into the dorsal surface of the base of proximal phalanx of thumb.

F u n c t i o n: it extends the proximal phalanx of the thumb (thus straightening the thumb), and participates in abduction of the thumb.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: posterior interosseous artery, radial artery.

The extensor pollicis longus muscle (m. exténsor póllicic lóngus) originates from the lateral middle third of the posterior surface of the ulna and the interosseous membrane. Its tendon passes under the extensor retinaculum, through a groove on the posterior surface of radius. It is inserted into the dorsal surface of base of the distal phalanx of the thumb.

F u n c t i o n: Extension of the thumb.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: posterior interosseous artery, radial artery.

The extensor indicis muscle (m. exténsor índicis) originates from the posterior surface of ulna and the interosseous membrane. Its tendon passes underneath the extensor retinaculum, together with the tendon of the extensor of fingers, and is inserted into the dorsal surface of the proximal phalanx of the index finger.

F u n c t i o n: Extension of the index finger.

I n n e r v a t i o n: radial nerve.

B l o o d s u p p l y: posterior interosseous artery.

Questions for revision and examination

1. Into what groups are the muscles of the upper extremity divided according to their location and function?

2. Which muscles abduct the arm in the shoulder joint? Which muscles adduct it?

3. Name the supinator and pronator muscles of the upper extremity.

4. How many groups of muscles are there on the anterior side of the forearm? Name the muscles of each group.

5. What groups of muscles are there on the posterior side of the forearm? Name these muscles.

Muscles of the hand

Muscles of the hand are divided into three groups: muscles of the thenar eminence, muscles of the hypothenar eminence and the middle group of muscles (Fig. 109).
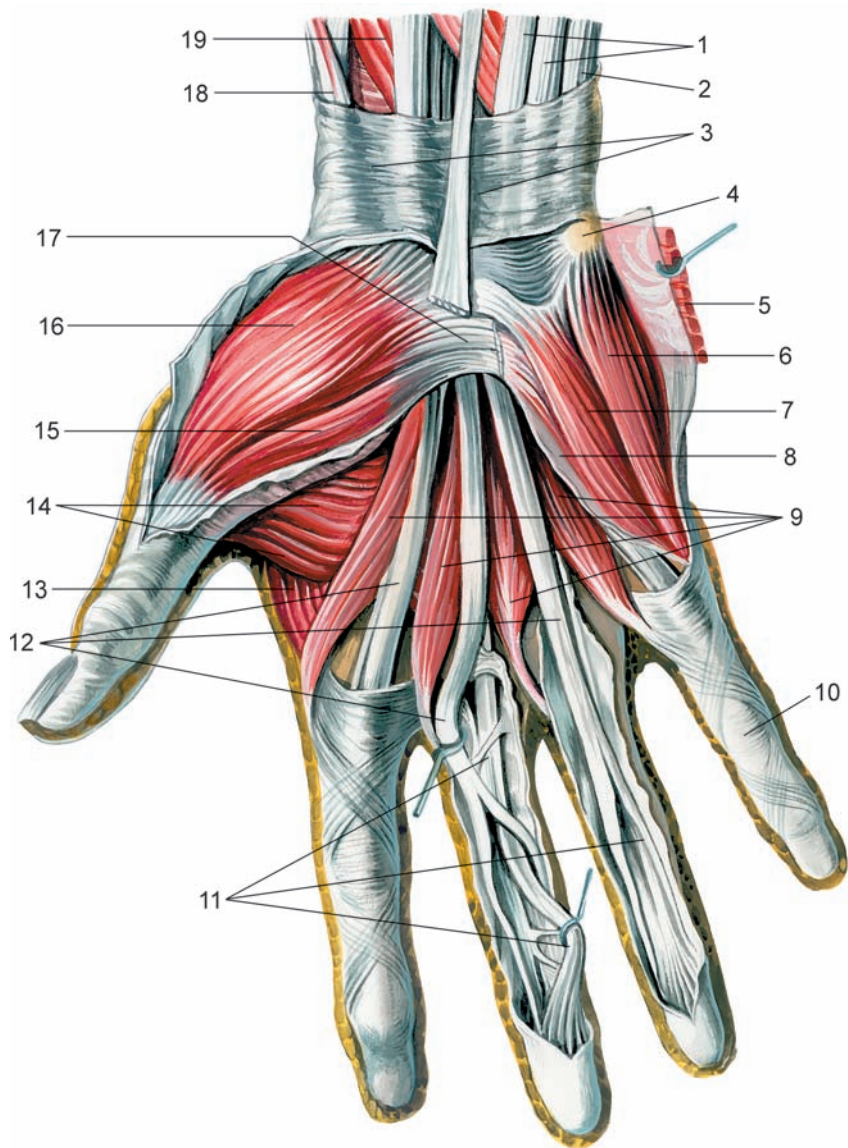
Fig. 109. Muscles of hand. Palmar side.

1 — tendons of flexor digitorum superficialis; 2 — tendon of flexor carpi ulnaris; 3 — fascia of forearm (partially removed); 4 — pisiform; 5 — palmaris brevis; 6 — abductor digiti minimi; 7 — flexor digiti minimi brevis; 8 — opponens digiti minimi; 9 — lumbricals; 10 — fibrous sheath of digiti minimi; 11 — tendons of flexor digitorum profundus; 12 — tendons of flexor digitorum superficiale; 13 — dorsal interosseal muscle (1st); 14 — adductor pollicis; 15 — flexor pollicis brevis; 16 — abductor pollicis brevis; 17 — flexor retinaculum; 18 — tendo of abductor pollicis longi; 19 — flexor pollicis longus.

The abductor pollicis brevis muscle (m. abdúctor póllicis brévis) is flat and is situated superficially (Fig.110). It originates from the scaphoid and trapezium bones and from the lateral region of the flexor retinaculum. The muscle stretches lateral and downwards to be inserted into the lateral edge of the base of the proximal phalanx of the thumb and the lateral edge of the tendon of extensor pollicis longus.

F u n c t i o n: Abduction of the thumb.

I n n e r v a t i o n: median nerve.

B l o o d   s u p p l y: superficial palmar branch of the radial artery.
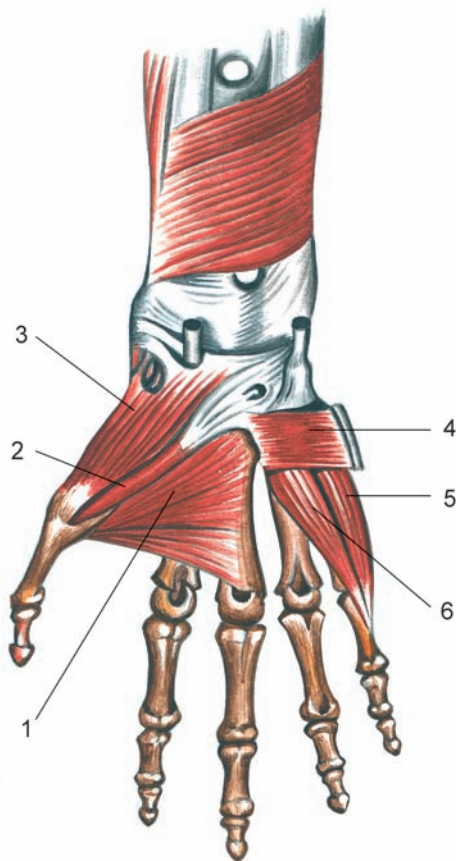
Fig. 110. Muscles of thenar and hypothenar.

1 — adductor pollicis; 2 — flexor pollicis brevis; 3 — abductor pollicis longus; 4 — palmaris brevis; 5 — abductor digiti minimi; 6 — flexor digiti minimi.

The opponens pollicis muscle (m. oppónens póllicis) is partially covered by the short abductor muscle of the thumb. Often if unites with the short flexor of the thumb. This muscle originates from the trapezium bone and the flexor retinaculum, and is inserted into the anterior surface of the first metacarpal bone.

F u n c t i o n: Opposition of the thumb to the other fingers.

I n n e r v a t i o n: median nerve.

Blood supply: superficial palmar branch of the radial artery, superficial palmar arch.

The flexor pollicis brevis muscle (m. fléxor póllicis brévis) is partially covered by the short abductor of the thumb. It has a superficial and a deep heads. The s u p e r f i c i a l   h e a d originates from the flexor retinaculum. The d e e p   h e a d originates from the trapezium, trapezoid and second metacarpal bones. The muscle is inserted into the proximal phalanx of the thumb.

F u n c t i o n: It flexes the proximal phalanx of the thumb (thus bending the thumb) and participates in its adduction.

I n n e r v a t i o n: superficial head — the median nerve; deep head — the ulnar nerve.

B l o o d   s u p p l y: superficial palmar branch of radial artery, deep palmar arch.

The adductor pollicis muscle (m. addúctor póllicis) is located in the middle of the thenar region. It lies beneath the tendons of the long flexors of fingers and the lumbrical muscles. It has an oblique and a transverse heads. Its o b l i q u e   h e a d originates on the capitate bone and bases of II and III metacarpals. The t r a n s v e r s e   h e a d originates from the anterior surface of the III metacarpal bone. The common tendon of this muscle is inserted into the base of the proximal phalanx of the thumb.

F u n c t i o n: It adducts the thumb to the index finger and participates in its flexion.

I n n e r v a t i o n: ulnar nerve.

B l o o d   s u p p l y: superficial palmar arch, deep palmar arch.

Muscles of the hypothenar

The palmaris brevis muscle (m. pálmaris brévis) originates from the flexor retinaculum and is inserted into the skin of the medial edge of the hand. This muscle is not always present.

F u n c t i o n: It wrinkles the skin of the hypothenar region.

I n n e r v a t i o n: ulnar nerve.

B l o o d   s u p p l y: ulnar artery.

The abductor digiti minimi brevis muscle (m. abdúctor dígiti mínimi) begins as a thin plate on the flexor retinaculum and the pisiform bone. It is inserted into the medial side of the proximal phalanx of the little finger.

F u n c t i o n: Abduction of the little finger.

I n n e r v a t i o n: ulnar nerve.

B l o o d   s u p p l y: deep palmar branch of ulnar artery.

The opponens digiti minimi muscle (m. oppónens dígiti mínimi) is a thin muscle, which originates on the flexor retinaculum and hook of hamate bone. It is inserted into the medial surface of the fifth metacarpal bone.

F u n c t i o n: opposition of the little finger (bringing it toward the thumb).

I n n e r v a t i o n: ulnar nerve.

B l o o d   s u p p l y: deep palmar branch of the ulnar artery.

The flexor digiti minimi brevis muscle (m. fléxor dígiti mínimi) is a thin band; it originates from the hook of the hamate bone and the flexor retinaculum. It is inserted into the palmar surface of the proximal phalanx of the fifth finger.

F u n c t i o n: Flexion of the little finger.

I n n e r v a t i o n: ulnar nerve.

B l o o d   s u p p l y: deep palmar branch of the ulnar artery.

Middle group of the muscles of the hand

The lumbrical muscles (mm. lúmbricales) are four thin fusiform muscles, which are situated beneath the palmar aponeurosis. They originate from tendons of the deep flexor of the fingers. The first and second lumbrical muscles originate from the radial edge of tendons, directed towards the index and middle fingers; the third lumbrical originates from adjoining edges of the tendons, which are inserted into the middle and fourth fingers; the fourth lumbrical originates from adjoining edges of tendons of the fourth and little fingers. The lumbrical muscles stretch to the radial sides of II–V fingers and attach on the dorsal side of their proximal phalanges.

F u n c t i o n: They flex the proximal phalanges and straighten the middle and distal phalanges of fingers II–V.

I n n e r v a t i o n: first and second lumbricals—the median nerve; third and fourth — the ulnar nerve.

B l o o d   s u p p l y: superficial palmar arch, deep palmar arch.

The palmar interossei muscles (mm. interóssei palmáres) are three muscles, situated on the carpal side of the hand, in the II, III and IV inter-

metacarpal spaces. They originate from medial edges of the second and lateral edges of fourth and fifth metacarpals. They are inserted into the dorsal side of proximal phalanges of fingers II, IV and V.

F u n c t i o n: They adduct fingers II, IV and V to the third finger.

I n n e r v a t i o n: ulnar nerve.

B l o o d s u p p l y: superficial palmar arch.

The dorsal interossei muscles (mm. interóssei dorsáles) are four pennate muscles, situated in the dorsal parts of the intermetacarpal spaces. Each originates by two heads on the adjacent sides of I–V metacarpals. The tendon of the first dorsal interosseous muscle is inserted into the radial side of proximal phalanx of the index finger; the second — on the radial side of the proximal phalanx of middle finger; the third — on the ulnar side of the proximal phalanx of the middle finger; and fourth — on the ulnar side of the proximal phalanx of the fourth finger (table 14).

F u n c t i o n: Abduction of the I, II, IV and V fingers from the third finger.

I n n e r v a t i o n: ulnar nerve.

B l o o d s u p p l y: deep palmar arch, dorsal metacarpal arteries.

Table 14. Muscles of the upper extremity.

Muscle	Origin	Insertion	Action	Innervation
I. Muscles of the shoulder girdle				
Deltoid	Acromial end of clavicle, acromion and scapular spine	Deltoid tuberosity of humerus	Whole muscle abducts the arm to horizontal level; the clavicular part flexes the arm; spinous part extends the arm	Axillary nerve
Supraspinatus	Supraspinous fossa of scapula and supraspinous fascia	Greater tubercle of humerus and capsule of shoulder joint	Abduction of the arm; stretching of the articular capsule	Suprascapular nerve
Infraspinatus	Infraspinous fossa of scapula and infraspinous fascia	Greater tubercle of humerus	Lateral rotation of the arm	Same as above
Teres minor	Lateral margin of scapula and infraspinous fascia	Greater tubercle of humerus	Lateral rotation of the arm	Axillary nerve
Teres major	Inferior angle of scapula and infraspinous fascia	Crest of the lesser tubercle of humerus	Medial rotation and adduction of the arm	Subscapular nerve

II. Muscles of the free upper extremity Muscles of the arm (anterior group):				
Coracobrachialis	Coracoid process of scapula	Humerus, below the crest of the lesser tubercle	Flexion and adduction in the shoulder joint	Musculo-cutaneous nerve
Biceps brachii	Long head: supraglenoid tubercle of scapula; short head: coracoid process	Radial tuberosity and bicipital aponeurosis	Flexion and supination of forearm in the elbow joint; flexion in the shoulder joint	Same as above
Brachialis	Humerus, distal of the deltoid tuberosity	Tuberosity of ulna	Flexion of forearm	Same as above
Posterior group:				
Triceps brachii	Long head: infraglenoid tubercle; medial and lateral heads: posterior surface of the body of humerus	Olecranon process of ulna	Extension of forearm in elbow joint; long head extends and adducts the arm	Radial nerve
Anconeus	Lateral epicondyle of humerus	Olecranon and posterior surface of ulna	Extension of forearm in the elbow joint	Same as above
Muscles of the forearm Anterior group Superficial (first) layer:				
Brachioradialis	Lateral supracondylar crest of humerus and lateral intermuscular septum of arm	Radius, above the styloid process	Flexion of arm and setting it in a middle position between supination and pronation	Radial nerve
Pronator teres	Medial epicondyle of humerus and coronoid process of ulna	Lateral surface of radius	Pronation and flexion of the forearm	Median nerve
Flexor carpi radialis	Medial epicondyle of humerus, medial intermuscular septum of arm and antebrachial fascia	Palmar surface of bases of the II–III metacarpal bones	Flexion of the wrist, abduction of the hand, and flexion of the forearm	Same as above
Palmaris longus	Medial epicondyle of humerus, medial intermuscular septum of arm	Palmar aponeurosis	Stretches the palmar aponeurosis and flexes the forearm and hand	Same as above
Flexor carpi ulnaris	Medial epicondyle of humerus, medial intermuscular septum of arm,	Pisiform and hamate bones and base of the fifth metacarpal	Flexion of the wrist, abduction of the hand and flexion of the forearm	Ulnar nerve

	olecranon and antebrachial fascia			
Second layer:				
Flexor digitorum superficialis	Medial epicondyle of humerus, coronoid process of ulna and antebrachial fascia	Four tendons insert on palmar surface of middle phalanges of II–V fingers. Near the shafts of proximal phalanges each tendon splits into two parts, beneath which pass the tendons of the deep flexor	Flexion of middle phalanges of fingers II–V; flexion of the hand and forearm	Median nerve
Third layer:				
Flexor digitorum profundus	Anterior surface of ulna, interosseous membrane of the forearm	Four tendons insert on distal phalanges of fingers II–V	Flexion of distal phalanges of fingers II–V and flexion of the hand	Median and ulnar nerves
Flexor pollicis longus	Same as above	Palmar surface of distal phalanx of the first finger	Flexion of the thumb and hand	Median nerve
Deep (fourth) layer:				
Pronator quadratus	Anterior margin and medial anterior surface of ulna	Anterior surface of radius (its lower quarter)	Pronation of the forearm and hand	Same as above
Posterior group **Superficial layer:**				
Extensor carpi radialis longus	Lateral epicondyle of humerus, lateral intermuscular septum of arm	Dorsal surface of base of the second metacarpal bone	Extension and abduction of the hand; flexion of the forearm	Radial nerve
Extensor carpi radialis brevis	Lateral epicondyle of humerus and antebrachial fascia	Dorsal surface of base of the third metacarpal bone	Extension and abduction of the hand	Same as above
Extensor digitorum	Same as above	Four tendons insert on dorsal surfaces of middle and distal phalanges of II–V fingers (dorsal aponeurosis of fingers)	Extension of fingers II–V and extension of the hand	Same as above
Extensor digiti minimi	Same as above	Dorsal surface of middle and distal	Extension of the little finger	Same as above

		phalanges of the little finger (into its dorsal apo-neurosis)		
Extensor carpi ulnaris	Same as above	Dorsal surface of the base of the fifth metacarpal	Extension and ab-duction of the hand	Same as above
Deep layer:				
Supinator	Lateral epicondyle of humerus, ulna	Proximal third of the lateral surface of radius	Supination of the forearm	Radial nerve
Abductor pollicis longus	Dorsal surface of radius and ulna, and interosseous membrane of fore-arm	Dorsal surface of the base of the first metacarpal	Abduction of the thumb and hand	Same as above
Extensor pollicis brevis	Dorsal surface of radius, in-terosseous mem-brane of forearm	Dorsal surface of the base of the proximal phalanx of thumb	Extension of the proximal phalanx of thumb	Same as above
Extensor pollicis longus	Dorsal surface of ulna, interosseous membrane of fore-arm	Dorsal surface of the base of the distal phalanx of thumb	Extends the thumb	Same as above
Extensor indicis	Same as above	Dorsal surface (aponeurosis) of the proximal pha-lanx of index fin-ger	Extension of the index finger	Same as above
Muscles of the hand **Muscles of the thenar:**				
Abductor pollicis brevis	Scaphoid and tra-pezium bones, flexor retinaculum of the hand	Lateral border of the base of the proximal phalanx of thumb	Abduction of the thumb	Median nerve
Flexor pollicis brevis	Trapezium and trapezoid bones, flexor retinaculum of the hand, sec-ond metacarpal bone	Anterior surface of the base of the proximal phalanx of thumb	Flexion of the thumb	Median and ulnar nerves
Opponens pollicis	Trapezium bone, flexor retinaculum of the hand	Lateral border and anterior surface of first metacarpal	Opposition of the thumb to the little finger	Median nerve
Adductor pollicis	Capitate bone, bases and anterior surfaces of II and III metacarpals	Base of the proxi-mal phalanx of thumb	Adduction of the thumb	Ulnar nerve

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Muscles of the hypothenar				
Palmaris brevis	Flexor retinaculum of the hand	Skin of the medial border of the hand	Wrinkles skin of the hypothenar region	Ulnar nerve
Abductor digiti minimi	Flexor retinaculum of the hand and pisiform bone	Medial border of the base of the proximal phalanx of little finger	Abducts the little finger	Same as above
Flexor digiti minimi brevis	Hook of the hamate bone and flexor retinaculum of hand	Palmar surface of the proximal phalanx of little finger	Flexion of the little finger	Same as above
Opponens digiti minimi	Same as above	Medial border and anterior surface of fifth metacarpal bone	Opposition of little finger to thumb	Same as above
Middle group of muscles				
Lumbricals	Tendons of the deep flexor of fingers	Dorsal surface (aponeurosis) of the proximal phalanges of II–V fingers	Flexion of the proximal phalanges; extension of the middle and distal phalanges	First and second lumbricals — median nerve; third and fourth — ulnar nerve
Palmar interossei	Medial border of II and lateral borders of IV and V metacarpal bones	Dorsal surface (aponeurosis) of proximal phalanges of fingers II, IV and V	Adduction of fingers II, IV and V to the third finger	Ulnar nerve
Dorsal interossei	Adjacent surfaces of I–V metacarpals	Dorsal surfaces (aponeurosis) of proximal phalanges of II–V fingers	Abduction of fingers II, IV and V from the third finger	Same as above

FASCIAE AND SYNOVIAL BURSAE OF THE UPPER EXTREMITY

Corresponding to topography, the fasciae of the upper extremity are named the deltoid fascia, infraspinous and supraspinous fasciae and brachial, antebrachial and hand fasciae.

The deltoid fascia (fáscia deltoídea) covers the deltoid muscle on the outside. At the front the fascia continues into the fascia of the thorax. Laterally and downward it passes into the brachial fascia. In the back the deltoid fascia accretes with the i n f r a s p i n o u s   f a s c i a, which covers the infraspinous and teres minor muscles.

The supraspinatus and infraspinatus fasciae are weakly developed. They cover the homonymous muscles and attach along the edges of the homonymous fossae of the scapula. The axillary fossa is lined by the a x i l l a r y   f a s c i a (fáscia axilláris).

The brachial fascia (fáscia bráchii) encases the muscles of the arm. Its distal end continues into the antebrachial fascia. On the arm it forms intermuscular septa between separate groups of muscles. The m e d i a l   i n t e r m u s c u l a r   s e p t u m   o f   t h e   a r m is relatively thick and is attached along the medial margin of the humerus. It separates the brachial and coracobrachial muscles from the medial head of the triceps. The l a t e r a l   i n t e r m u s c u l a r   s e p t u m   o f   t h e   a r m separates the brachial and brachioradial muscles from the lateral head of triceps. This septum attaches along the lateral margin of the humerus. The distal ends of these intermuscular septa serve as points of origin for several forearm muscles.

The antebrachial fascia (fáscia antebráchii) is much better developed than the brachial, especially on the dorsal surface of the forearm. It forms a thick sheath around the muscles of the forearm, giving off intermuscular septa towards the bones. In the back it is attached to the posterior margin of the humerus and the olecranon process. In the proximal front region this fascia is strengthened by fibers of the b i c i p i t a l   a p o n e u r o s i s, or Piragoff's fascia. In the region of the wrist it has a thickening, which forms the flexor and extensor retinacula. These tendon retinacula help to create optimal conditions for utilizing the force developed by muscles of the forearm. The f l e x o r   r e t i n a c u l u m (r e t i n á c u l u m f l e x ó r u m) attaches to the pisiform and hamate bones medially, and the scaphoid and trapezium on the lateral. It passes over the carpal groove, turning it into the c a r p a l   t u n n e l (c a n á l i s   c á r p i).

The carpal tunnel contains two synovial sheaths for tendons of the flexor muscles. The c o m m o n   f l e x o r   s h e a t h (v a g í n a   c o m m ú n i s   t e n d i n u m   m u s c u l ó r u m   f l e x ó r u m) confines the tendons of the superficial and deep flexors of the fingers. The t e n d i n o u s s h e a t h   o f   t h e   f l e x o r   p o l l i c i s   l o n g u s (v a g í n a   t é n d i n i s m.   f l é x o r i s   p ó l l i c i s   l ó n g i) is occupied by the tendon of the homonymous muscle. This sheath extends up to the base of the distal phalanx of thumb. The common synovial flexor sheath ends at the middle of the palm, except for its lateral part, which extends up to the distal phalanx of the little finger. The f i b r o u s   a n d   s y n o v i a l   s h e a t h s   o f   f i n g e r s   I I – I V   o f   h a n d (v a g í n a e   f i b r ó s a e   e t   s y n o v i á l e s   d i g i t ó r u m   m a n u s) have a blind beginning at the level of metacarpophalangeal joints, and extend to bases of the distal phalanges. Due to the described structure of the synovial sheaths of the hand, purulent processes spread much faster (along the sheaths) from the I and V fingers than from the others.

The lateral and medial sections of the flexor retinaculum are separated from the rest of it, forming two small tunnels. The lateral tunnel contains the t e n d i n o u s s h e a t h o f f l e x o r c a r p i r a d i a l i s (v a g í n a t é n d i n i s m. f l é x o r i s c á r p i r á d i a l i s). The medial tunnel contains the ulnar nerve, artery and vein.

The extensor retinaculum (retináculum extensórum) stretches across the dorsal side, from the distal end of the radius to the styloid process of the ulna and the ulnar collateral ligament. The space beneath the retinaculum is divided by fibrous fascicles into six tunnels, which contain tendons of the extensor muscles of the wrist and fingers, and their synovial sheaths. The first tunnel, starting at the lateral edge of the retinaculum, contains tendons of the long abductor and the short extensor of thumb. The second tunnel contains tendons of the long and short radial extensors of wrist; the third contains the tendon of the long extensor of thumb; the fourth — tendons of the extensor of the fingers and extensor of the index finger; the fifth — tendon of the extensor of little finger; and the medial most tunnel contains the tendon of the ulnar extensor of the wrist. The proximal ends of these sheaths protrude 2–3 cm from underneath the retinaculum. The distal ends extend to the middle of the metacarpal bones.

The fascia of the hand (fáscia mánus) is better developed on the palmar side, where it covers the muscles of the thenar and hypothenar, tendons of the flexors of the fingers and the lumbrical muscles. Around the middle of the palm this fascia forms **the palmar aponeurosis (aponeurósis palmáris)**. This aponeurosis has a triangular shape. Its apex is directed towards the forearm, where it serves as a point of insertion for the long palmar muscle. At the bases of the fingers this aponeurosis divides into fibrous cords, which continue onto the fingers and participate in the formation of fibrous tunnels for the tendons of the superficial and deep flexors of fingers. Fibrous fascicles of these tunnels and of the palmar aponeurosis weave into the skin, which results in the formation of characteristic grooves on the surface of the hand.

The d e e p l a m i n a o f t h e p a l m a r f a s c i a (intermuscular fascia) separates interosseous muscles of the hand from tendons of the forearm muscles. This lamina is weakly developed.

The dorsal fascia of the hand (fáscia dorsális mánus) has a superficial and a deep plate. The s u p e r f i c i a l l a m i n a is weakly developed; it stretches from the distal end of the extensor retinaculum over the tendons of the extensors. The d e e p l a m i n a is better developed. It covers the interosseous muscles and attaches to the periosteum on the dorsal surface of metacarpal bones.

1. Name the muscles of the thenar, the hypothenar and the middle group of the muscles of the hand.

2. How many synovial tendon sheaths are there beneath the flexor retinaculum on the palmar side of the wrist?

3. How far does the synovial sheath of the flexors of each finger extend in the proximal direction?

4. Tendons of which muscles pass through synovial sheaths on the dorsal side of the wrist?

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE UPPER EXTREMITY

The upper extremity has several bone and muscle structures that are easily definable surfaces. These include the scapular spine, acromion, medial and lateral margins and the inferior angle of the scapula. In the subclavicular region one can palpate the coracoid process. The deltoid region, which is occupied by the large deltoid muscle, is separated from the greater pectoral muscle by the deltopectoral groove. The axillary region corresponds **to the axillary fossa**, which can be seen when the arm is raised. The anterior border of this fossa is the lower edge of the greater pectoral muscle, and the posterior border is the lower edge of the latissimus dorsi. On the arm there are a medial and a lateral grooves, which continue into the cubital fossa. At the sides of the elbow it is possible to palpate the medial and lateral epicondyles of the humerus. On the dorsal side of the elbow joint is the prominent olecranon process. On the anterior surface of the forearm are the r a d i a l a n d u l n a r g r o o v e s, and at the level of the radiocarpal joint it is possible to palpate the styloid processes of the ulna and radius. On the palm one can easily see the thenar and hypothenar, and between them a triangular depression. Also well definable are the creases over metacarpophalangeal and interphalangeal joints and the balls of the fingers. The dorsal surface of the hand is convex. At the base of the thumb, when it is abducted, a fossa appears between tendons of the long and short extensors. This fossa is called the anatomical snuffbox; in it lies the radial artery, which passes between the first two fingers onto the palm.

The skin on the scapular region is thick and tightly accreted with the subcutaneous tissue and the superficial fascia. The skin above the deltoid muscle is also thick and almost immovable.

In the subclavicular region the skin is thin, and the subcutaneous tissue is well developed, especially in women. The axillary region, which confines the axillary fossa, is bordered medially by the level of the third rib. Its lateral border is a line drawn on the arm between points of insertion of the

latissimus dorsi and pectoralis major muscles. Beginning in puberty, the skin of the axillary region acquires characteristic hair growth. The skin of this region contains many sweat and sebaceous glands; the subcutaneous tissue is weakly developed. On the arm the skin is thicker on the posterior and lateral sides than on the medial; the subcutaneous tissue is loose. On the elbow joint the skin is thick on its posterior surface and thin in the front. Above the apex of the olecranon there is a subcutaneous synovial bursa. In cases of injury or prolonged compression this bursa is likely to be a site of pathological processes. On the front of the forearm the skin is thin and relatively movable, whereas on the posterior side it is thicker and has less mobility. On the palm the skin is thick and lacks hair. Its subcutaneous tissue has a cellulate structure. On the dorsal side of the hand the skin is thin and movable. The subcutaneous tissue is loose, which contributes to formation of an edema during inflammatory processes in the hand.

The subcutaneous tissue contains almost no adipose cells. The skin is attached by fibers to the proper fascia of the trapezius muscle. The fascia of the supraspinous muscle is attached at the top to the transverse ligament of the scapula, the coracoid process and the capsule of the shoulder joint. Between the supraspinous muscle and the floor of the supraspinous fossa there is a thin layer of fatty tissue, which contains the supraspinous nerve, artery and veins.

The loose connective tissue beneath the infraspinous muscle contains the circumflex artery of scapula. The supraspinous and infraspinous fascial sheaths communicate with each other near the base of the acromion (where blood vessels and nerves enter the infraspinous fossa).

The subdeltoid connective tissue space continues downward until the insertion point of the deltoid muscles. This space contains the tendon of the long head of biceps brachii, branches of the axillary nerve and the posterior circumflex humeral artery.

Beneath the axillary fascia is **the axillary cavity (cavum axillare)**, which is shaped like a pyramid, the apex of which is directed upward and medially, and the base — downward and laterally. The upper aperture of the axillary cavity is bordered by the clavicle, the first rib and the superior margin of the clavicle. This aperture connects the axillary and the cervical regions. The axillary cavity has four walls. The anterior wall is formed by the major and minor pectoral muscles; the posterior — by the latissimus dorsi, teres major and subscapular muscles; the medial wall is formed by the serratus anterior muscle; and the lateral — by the biceps brachii and the coracobrachialis muscle.

The posterior wall of the axillary cavity has two relatively large openings, which are normally covered by loose connective tissue. The trila-

teral opening is more medial, and is bordered by the subscapular muscle at the top, the teres major muscle at the bottom, and by the long head of the triceps on the lateral side. Through this opening pass the circumflex scapular artery and vein. The quadrilateral opening is more lateral; it is bordered by the surgical neck of humerus on the lateral side, the long head of the triceps on the medial side, the subscapular muscle at the top, and the major teres muscle at the bottom. This foramen serves as a passage for the posterior circumflex humeral artery and vein and the axillary nerve. The axillary cavity contains a lot of loose fibrous connective tissue rich in adipocytes, as well as blood vessels, nerves and axillary lymph nodes.

On the anterior wall of the axillary fossa there are three triangles, the borders of which define the topography of some blood vessels and nerves. The clavipectoral triangle is situated between the clavicle and the upper edge of the minor pectoral muscle. Within its boundaries lie the axillary artery and vein and the medial bundle of the brachial plexus.

The pectoral triangle corresponds to the contours of the minor pectoral muscle. Within its boundaries lie the long thoracic nerve and the lateral thoracic artery branches off the axillary artery. Through **the subpectoral triangle**, which is situated between the lower boundaries of the minor and greater pectoral muscles, pass the axillary artery and vein, as well as the median, musculocutaneous, ulnar and other nerves. Within this triangle the axillary artery gives off the subscapular and the anterior and posterior circumflex humoral arteries.

The neurovascular bundle, formed by the median nerve and the brachial artery and veins, passes on the arm through the medial sulcus (of the biceps muscle). On the back of the arm the proper fascia forms a sheath for the triceps muscle. In front of this sheath, through the radial canal, passes the posterior neurovascular bundle. The radial, or **humeromuscular, canal (canális nérvi radiális, s. canális humeromusculáris)** is situated between the posterior surface of the humerus and the triceps brachii muscle. Its upper opening (entrance) is situated at the boundary between the upper and middle thirds of the body of the humerus. At the medial side this opening is bordered by the humerus and the lateral and medial heads of triceps brachii muscle. Its lower opening (exit) is situated at the boundary between the middle and bottom thirds of humerus, between the brachialis and brachioradialis muscles. This canal serves as a passage for the radial nerve and the deep brachial artery and veins. On the back of the elbow, on either side of the olecranon process, there are two grooves. In the posterior medial cubital groove, within a tunnel, formed by the medial epicondyle, the olecranon and the fascia, lies the ulnar nerve.

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Situated on the front cubital surface is **the cubital fossa (fóssa cubitális)**. Its bottom and upper border are formed by the brachioradialis muscle and the pronator teres. The cubital fossa contains a l a t e r a l and m e d i a l b i c i p i t a l g r o o v e s. The lateral groove is bordered by the brachioradialis muscle on the lateral side, and the brachialis muscle medially. The medial bicipital groove is situated between the pronator teres and the brachialis muscle. Situated in the subcutaneous tissue of this region are the basilic and cephalic veins. Beneath the bicipital aponeurosis pass the brachial artery and veins, and the median nerve. On the anterior cubital region there are three fascial muscle sheaths. The medial one contains the pronator teres, flexor carpi radialis, palmaris longus muscle, flexor carpi ulnaris muscles and, at the very bottom, the flexor digitorum superficialis. The lateral sheath contains the brachioradialis muscle and, beneath it, the supinator. The middle fascial sheath, which lies between the two bicipital grooves, encases the distal part of the biceps brachii and its tendon, and the anconeus muscle. In the anterior forearm region, on the antebrachial fascia there are three grooves called the radial, median and ulnar. The radial groove is situated between the brachioradialis muscle and the flexor carpi radialis. The median groove passes between the flexor carpi radialis and the flexor digitorum superficialis. The ulnar groove is bordered by the flexor digitorum superficialis and the flexor carpi ulnaris.

The antebrachial fascia gives off two intermuscular septa toward the radius, which separate the anterior, posterior and lateral fascial sheaths of the forearm. Each of these sheaths contains muscles, together with nerves and blood vessels. The largest one is the anterior fascial sheath. It contains the anterior muscles of the forearm, excluding the brachioradialis muscle, situated in four corresponding layers. Between the flexor digitorum profundus and the flexor pollicis longus there is a connective tissue space (or Pirogoff), filled by loose connective tissue. Situated beneath all the muscles, on the interosseous membrane, is a neurovascular bundle, which is formed by the anterior interosseous blood vessels and nerves.

The lateral fascial sheath contains only three muscles. More superficially lies the brachioradialis muscle, and beneath it — the extensor carpi radialis longus and extensor carpi radialis brevis muscles.

The posterior sheath contains the posterior muscles of the forearm, excluding the extensor carpi radialis longus and extensor carpi radialis brevis. Between the superficial and deep layers of muscles lies the posterior brachial connective tissue space. The posterior and anterior connective tissue spaces communicate through an opening in the interosseous membrane of forearm, which serves as a passage for interosseous vessels. Within the posterior fascial sheath, on the interosseous membrane, lies a

neurovascular bundle, containing blood vessels and the deep branch of the radial nerve.

On the palm there are three i n t e r f a s c i a l s p a c e s, formed by two f a s c i a l s e p t a, which stretch from the superficial fascia to the III–V metacarpals. The lateral interfascial space contains the muscles of the thenar. The middle interfascial space has superficial and deep sections. Its superficial section contains tendons of the flexor digitorum superficialis and profundus, the superficial palmar arch and branches of the median and ulnar nerves. The deep section is situated between tendons of the flexors and the deep lamina of the palmar fascia. It contains the deep palmar arterial arch and its branches. The deep one communicates through the carpal tunnel with the space of Pirogoff, located on the anterior side of the forearm. The medial interfascial space contains the muscles of the hypothenar.

Questions for revision and examination

1. Name the walls of the axillary cavity. What muscles form each wall?
2. Name the triangle (and their borders) defined on the anterior wall of the axillary cavity.
3. Where is the radial canal situated, and by what muscles formed?
4. Name the muscles situated in each fascial sheath of the forearm.
5. Describe the fasciae of the hand and their location among the adjacent muscles.
6. Name the connective tissue spaces of the upper extremity (and their locations).

MUSCLES AND FASCIAE OF THE LOWER EXTREMITY

The lower extremities serve as organs of support and movement. Due to these functions they have the most powerful musculature, which makes up more then 50 percent of the total muscle mass of the body. The muscles of the lower extremity are divided, according to their location, into the muscles of the pelvis (pelvic girdle) and muscles of the free lower extremity (of the thigh, leg and foot) (Fig. 111 and 112).

MUSCLES OF THE PELVIC GIRDLE (MUSCLES OF THE PELVIS)

Muscles of the pelvis surround the coxal joint from all sides. They have points of origin on the hipbone, lumbar vertebrae and the sacrum, and are divided into external and internal groups of muscles. The internal muscles, which are situated inside the pelvic cavity, include the iliopsoas (consists of the iliacus and the psoas major muscles), psoas minor, obturator internus, superior gemellus and inferior gemellus, and the piriformis muscles. The external muscle group consists of muscles of the sides and of the gluteal regions of the pelvis. These include the gluteus maximus,

Fig. 111. Muscles of lower limb, right. Anterior aspect.

1 — sartorius; 2 — iliopsoas; 3 — pectineus; 4 — abductor longus; 5 — gracilis; 6 — triceps surae; 7 — soleus; 8 — tendon of extensor hallucis longus; 9 — inferior extensor retinaculum; 10 — superior extensor retinaculum; 11 — extensor digitorum longus; 12 — fibularis brevis; 13 — tibialis anterior; 14 — fibularis longus; 15 — quadriceps femoris; 16 — tensor fasciae latae.

gluteus medius and gluteus minimus muscles, as well as the quadratus femoris muscle, the tensor of fascia lata and the obturator externus muscle.

Internal muscles of the pelvic girdle

The iliopsoas muscle (m. iliopsóas) forms part of the posterior abdominal wall. This muscle consists of two parts with two different points of origin. These are the greater psoas and the iliac muscles (see «Muscles of the posterior abdominal wall). **The psoas major muscle** lies in front of the quadratus femoris muscle, adjoining the anterior surface of the lumbar vertebrae. It originates from the lateral surfaces of the bodies of the vertebrae, the intervertebral disks and the transverse processes. This muscle stretches downward, crosses the pelvic brim and unites with the iliac muscle. The iliac muscle is flattened and triangular in shape. It originates on walls of the iliac fossa of ilium, the internal lip of the iliac crest, and the iliolumbar and sacroiliac ligaments. The iliopsoas muscle passes beneath the inguinal ligament through the muscular lacuna, and is inserted into the lesser trochanter of femur.

F u n c t i o n: This muscle flexes the femur in the coxal joint. When the lower extremity is fixed, it flexes the lumbar section of the spine, bending the pelvis and trunk to the front.

I n n e r v a t i o n: lumbar plexus.

B l o o d supply: iliolumbar artery, deep circumflex iliac artery.

The psoas minor muscle (m. psoás mínor) lies on the anterior surface of the psoas major muscle. It originates on the lateral surfaces of the T12 and L1 vertebrae and the intervertebral disk. Its long tendon is inserted into the arcuate line of ilium and the iliopubical eminence. Part of its fibers continues into the iliac fascia and the iliopectineal arch.

Function: It stretches the iliac fascia, increasing the support for the iliopsoas muscle. This muscle also participates in flexion of the lumbar part of the spine.

Innervation: lumbar plexus.

Blood supply: lumbar arteries.

The internal obturator muscle (m. obturátor intérnus) is a flat, triangular muscle, with the apex of the triangle pointing down. It originates on the internal surface of the obturator membrane, the edges of the obturator foramen and the obturator fascia. It exits the pelvic cavity through the lesser sciatic foramen. Then it makes a sharp turn around the edge of the lesser sciatic notch and is inserted into the medial surface of the greater trochanter of femur.

F u n c t i o n: Supination of the femur.

I n n e r v a t i o n: lumbar plexus, sacral plexus.

B l o o d s u p p l y: inferior gluteal artery, obturator artery, internal pudendal artery.

The superior gemellus muscle (m. geméllus supérior) is short and flat; it originates from the ischial bone. The inferior gemellus muscle (m. gemellus inferior) is also flattened and short, and originates from the ischial tuberosity. Both muscles join the internal obturator muscle on the way out of the pelvic cavity and are inserted into the greater trochanter of femur.

F u n c t i o n: Supination of the thigh.

I n n e r v a t i o n: sacral plexus.

B l o o d   s u p p l y: inferior gluteal artery, obturator artery, internal pudendal artery.

The piriform muscle (m. pirifórmis) is spindle-shaped; it originates on the pelvic surface of the sacrum (S2–S4 vertebrae), lateral of the pelvic sacral foramina. It exits the pelvis through the greater sciatic foramen. Behind the neck of femur it continues into a tendon, which is inserted into the apex of the greater trochanter.

F u n c t i o n: This muscle supinates and slightly abducts the thigh.

I n n e r v a t i o n: sacral plexus.

B l o o d   s u p p l y: superior and inferior pudendal arteries

External muscles of the pelvic girdle

The external muscles of the pelvic girdle are situated in three layers. The superficial layer consists of the gluteus maximus and the tensor fascia lata muscle (Fig. 113). The middle layer includes the gluteus medius and the quadrate muscle of the thigh. The deep layer is made up of the gluteus minimus and the obturator externus muscle. All of the above named muscles act upon the coxal joint.

The gluteus maximus muscle (m. glutéus máximus) is a thick tetragonal muscle, which forms the surface contour of the buttock. It originates on the crest of ischium, the tendinous origin of the erector muscle of the spine, the dorsal surface of the sacrum and coccyx and on the sacrotuberal ligament. The muscle stretches obliquely down and is inserted into the gluteal tuberosity of the femur. Between its tendon and the greater trochanter lies the trochanteric bursa of the gluteus maximus muscle.

F u n c t i o n: It extends and supinates the femur. When the lower extremity is fixed, this muscle straightens the body, and supports the balance of the pelvis and trunk. Its anterosuperior fascicles abduct the thigh and stretch the iliotibial tract, which holds the knee joint in an extended position. Its posteroinferior fascicles adduct and supinate the thigh.

I n n e r v a t i o n: inferior gluteal nerve.

B l o o d   s u p p l y: superior and inferior gluteal artery, medial circumflex artery of the thigh.

The gluteus medius muscle (m. glutéus médius) is thick and triangular; it is situated beneath the gluteus maximus. Its origin is on the external surface of ilium, between the anterior and posterior gluteal lines. The fascicles of this muscle converge downward and are inserted into the apex and lateral surface of the greater trochanter of the femur.
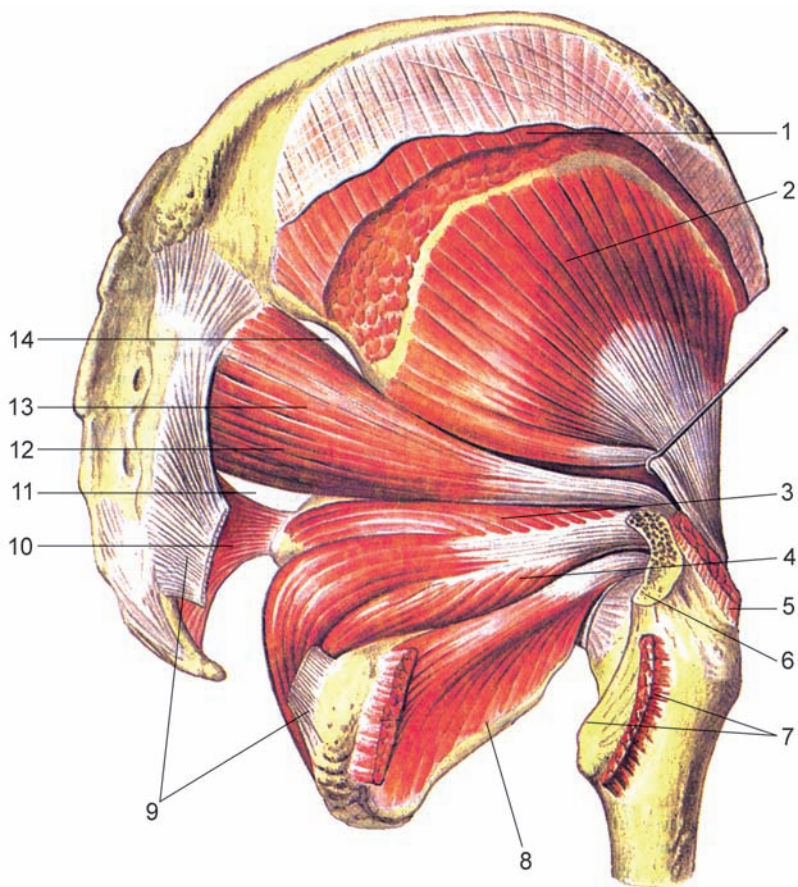
Fig. 113. External pelvic muscles. Mm. gluteus maximus, medius and quadratus femoris are removed.

1 — gluteus medius (cut); 2 — gluteus minimus; 3 — gemellus superior; 4 — gemellus inferior; 5 — gluteus medius (cut off); 6 — greater trochanter; 7 — quadratus femoris (cut off); 8 — obturator externus; 9 — sacrotuberal ligament; 10 — sacrospinous ligament; 11 — infrapiriform foramen; 12 — obturator internus; 13 — piriformis; 14 — suprapiriform foramen.

F u n c t i o n: It abducts the thigh. Its anterior fascicles pronate the femur, and the posterior fascicles supinate it. When the lower extremity is fixed, the gluteus medius and minimus muscles support the body in a vertical position.

I n n e r v a t i o n: superior gluteal nerve.

B l o o d   s u p p l y: superior gluteal artery, lateral circumflex artery of the thigh.

The gluteus minimus muscle (m. glutéus mínimus) is flat and triangular, and is situated beneath the gluteus medius muscle. It originates from the outer surface of the ilium, between the middle and inferior gluteal lines, on the edge of the greater sciatic notch. It narrows towards the bottom and is inserted into a short tendon on the anterolateral surface of the greater trochanter. Between its tendon and the greater trochanter lies the trochanteric bursa of the gluteus minimus muscle.

F u n c t i o n: It abducts the thigh. Its anterior fascicles participate in pronation of the femur, and the posterior — in its supination.

I n n e r v a t i o n: superior gluteal nerve.

B l o o d s u p p l y: superior gluteal artery, lateral circumflex artery of thigh.

The tensor of fascia lata muscle (m. ténsor fásciae látae) is a flat, long strap muscle, narrow towards the bottom. It is situated on the lateral side of the thigh, between the superficial and deep laminae of the fascia lata. It originates on the superior anterior iliac spine and the adjacent part of the iliac crest. At the level of the upper and middle thirds of the hip it continues into the iliotibial tract, which stretches down and attaches to the lateral condyle of tibia.

F u n c t i o n: This muscle stretches the fascia lata and supports the knee joint in a straightened position. It also flexes the thigh.

I n n e r v a t i o n: superior gluteal nerve.

B l o o d s u p p l y: superior gluteal artery, lateral circumflex artery of the thigh.

The quadratus femoris muscle (m. quadrátus fémoris) is a flat tetragonal muscle, situated between the inferior gemellus and the great adductor muscles. It originates on the upper part of the ischial tuberosity and is inserted into the upper part of the intertrochanteric crest. Between the anterior part of the muscle and greater trochanter there is often a synovial bursa.

F u n c t i o n: Supination of the thigh.

I n n e r v a t i o n: sciatic nerve.

B l o o d s u p p l y: inferior gluteal artery, obturator artery, medial circumflex artery of the thigh.

The obturator externus muscle (m. obturátor extérnus) is triangular; it originates on the external surfaces of the obturator membrane, the pubic bone and the ramus of the ischial bone. Its fascicles are directed to the back, laterally and upwards. They continue into a tendon, which is inserted into the trochanteric fossa of the greater trochanter and to the capsule of the hip joint.

F u n c t i o n: Supination of the thigh.

Innervation: obturator nerve.

Blood supply: obturator artery and the lateral circumflex femoral artery.

MUSCLES OF THE FREE LOWER EXTREMITY

Muscles of the thigh are divided into three groups: the anterior (flexors of the thigh and extensors of the leg), posterior (extensors of the thigh), and medial (adductors of the thigh). These muscles have a considerable mass and length, and are capable of developing significant force.

Anterior muscles of the thigh

The sartorius (m. sartórius) is a narrow strap muscle. It originates on the superior anterior iliac spine and stretches obliquely down and medially. Its tendon is inserted into the tibial tuberosity and into the crural fascia. Close to its point of insertion, the tendon of the sartorius muscles accretes with tendons of the gracilis and semimembranosus muscles, forming a triangular fibrous lamina called the superficial goose's foot.

Function: It flexes the thigh and leg, and abducts and supinates the thigh.

Innervation: femoral nerve.

Blood supply: muscular branches of the femoral artery, lateral circumflex artery.

The quadriceps femoris muscle (m. quadríceps fémoris) takes up the anterior, anterolateral anteromedial surfaces of the thigh. It consists of four parts, which are the rectus muscle of thigh and the lateral, medial and intermediate vastus muscles of thigh. The rectus femoris muscle (m. réctus fémoris) originates on the inferior anterior iliac spine and the iliac bone, above the acetabulum. It stretches down in front of the coxal joint. The vastus lateralis muscle (m. vástus laterális) is the largest of the four parts. It originates from the intertrochanteric line, the lower part of the greater trochanter and the gluteal tuberosity. It stretches obliquely down and medially. The vastus medialis muscle (m. vástus mediális) originates from the lower half of the intertrochanteric line, the medial labium of the rough line of the femur and the medial intermuscular septum of thigh. It is directed obliquely down and laterally. The vastus intermedius muscle (m. vástus intermédius) is situated between the vastus medialis and vastus lateralis muscles and is partially covered by them. It originates on the anterior and lateral surfaces of the body of the femur, the lateral labium of the linea

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aspera and the lateral intermuscular septum of the thigh. It stretches downwards. The common tendon of the quadriceps femoris muscle is inserted into the side edges of the patella and the tibial tuberosity. Below the patella the central part of the ligament continues into the patellar ligament. Some fascicles of this tendon continue into the medial and lateral patellar retinacula.

F u n c t i o n: The quadriceps femoris muscle extends the leg in the knee joint. The rectus femoris muscle takes part in flexion of the femur.

I n n e r v a t i o n: femoral nerve.

B l o o d   s u p p l y: femoral artery, deep artery of the thigh.

Posterior muscles of the thigh

The biceps femoris muscle (m. bíceps fémoris) has a long and a short heads. The l o n g   h e a d originates from the upper medial surface of the ischial tuberosity and the sacrotuberal ligament. The s h o r t   h e a d originates on the lateral labium of the linea aspera, the upper part of the lateral epicondyle and the lateral intermuscular septum of the thigh. The two heads fuse on the lower third of the femur and continue into a flat tendon. This tendon stretches along the back lateral surface of the knee joint and is inserted into the head of fibula and the lateral epicondyle of femur. Part of its fascicles weaves into the crural fascia. Between the tendon of the biceps and the fibular collateral ligament there is a tendon bursa of the biceps femoris.

F u n c t i o n: It extends the thigh and flexes the leg. When the leg is bent in the knee joint this muscle slightly supinates it.

I n n e r v a t i o n: long head — the sciatic (tibial) nerve; short head— the common peroneal nerve.

B l o o d   s u p p l y: perforating arteries.

The semimembranosus muscle (m. semimembranósus) originates from the ischial tuberosity as a long tendinous lamina, which continues into a venter at midlevel of the thigh. This venter is situated in front of the semitendinous muscle and the long head of the biceps of the thigh. At the level of the knee joint the tendon of the semimembranosus muscle divides into three fascicles, which form the so-called «deep goose's-foot». One of these fascicles attaches to the tibial collateral ligament; the second forms the oblique popliteal ligament; and the third continues into the fascia of the popliteal muscle and is inserted into the soleus line of the tibia.

F u n c t i o n: This muscle extends the thigh and flexes the leg. When the leg is bent in the knee joint, this muscle pronates it.

I n n e r v a t i o n: sciatic (tibial) nerve.

B l o o d s u p p l y: medial circumflex artery of the thigh, perforating arteries, popliteal artery.

The semitendinosus muscle (m. semitendinósus) originates on the ischial tuberosity, next to the long head of the biceps of the thigh. On the middle third of the thigh its venter continues into a long tendon, which inserts on the proximal medial surface of the tibia. Its tendon, together with tendons of the gracilis and sartorius muscles, participates in formation of the «superficial goose's-foot».

F u n c t i o n: It extends the thigh and flexes the leg; when the knee joint is bent, this muscle pronates the leg.

I n n e r v a t i o n: tibial nerve.

B l o o d s u p p l y: perforating arteries.

Medial muscles of the thigh

The gracilis muscle (m. grácilis) is long and flat. It originates on the inferior side of the pubic symphysis and the inferior ramus of the pubis. On the lower thigh its venter is situated between the sartorius and the semimembranosus muscles. Its tendon is inserted into the upper medial part of the tibia, and participates in the formation of the «superficial goose's-foot».

F u n c t i o n: It adducts the thigh and also flexes and pronates the leg.

I n n e r v a t i o n: obturator nerve.

B l o o d s u p p l y: obturator artery, external pudendal artery, deep artery of the thigh.

The pectineus muscle (m. pectineus) originates on the crest and superior ramus of pubis. It is inserted into the proximal part of femur, between the back of the lesser trochanter and the linea aspera.

F u n c t i o n: It adducts the thigh and participates in its flexion.

I n n e r v a t i o n: obturator nerve.

B l o o d s u p p l y: obturator artery, external pudendal artery, deep artery of thigh.

The adductor longus muscle (m. addúctor lóngus) originates from a thick tendon on the external surface of pubis, between its crest and the pubic symphysis. This muscle covers from the front the adductor brevis and the upper part of the adductor magnus. It stretches down and laterally, is inserted into the medial labium of the linea aspera of the thigh.

F u n c t i o n: Adduction of the thigh. This muscle also takes part in flexion and supination of the thigh.

I n n e r v a t i o n: obturator nerve.

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B l o o d s u p p l y: obturator artery, external pudendal artery, deep artery of the thigh.

The adductor brevis muscle (m. addúctor brévis) originates from the external surface of the body and lower inferior ramus of the pubic bone. It is situated behind the pectineus and adductor longus muscles. Its fascicle stretches down and laterally, and is inserted into the linea aspera of femur.

F u n c t i o n: It adducts the thigh and takes part in its flexion.

I n n e r v a t i o n: obturator nerve.

B l o o d s u p p l y: obturator artery, perforating arteries.

The adductor magnus muscle (m. addúctor mágnus) is the largest muscle of the medial group. It originates on the ischial tuberosity, ramus of ischium and inferior ramus of pubis. It is situated behind the adductor longus, adductor brevis and in front of the semitendinosus and semimembranosus muscles and the long head of biceps femoris. It inserts along the whole length of the medial lip of linea aspera.

F u n c t i o n: This muscle adducts the thigh. Its medial fascicles participate in extension of the thigh.

I n n e r v a t i o n: obturator nerve, sciatic nerve.

B l o o d s u p p l y: obturator arteries, perforating arteries.

Questions for revision and examination

1. Into what groups are muscles of the pelvis divided? Name the muscles of each group.
2. Name the parts of the quadriceps muscle of thigh and their points of origin and insertion.
3. Name the muscles found on the back of the thigh. Where do they originate and where are they inserted into?
4. Which muscles act as adductors of the thigh? Where do they originate from and where are they inserted into?

MUSCLES OF THE LEG

Muscles of the leg are well developed and have wide points of origin, which is attributed to the natural erect position of the body and the role of the lower extremity in support and movement. The leg muscles are divided into anterior, lateral and posterior groups. The anterior group consists of the tibialis anterior muscle, extensor hallucis longus muscle and extensor digitorum longus muscle. The lateral group includes the long and short peroneal muscles. The posterior group consists of the triceps surae muscle and the plantaris muscle, which form the superficial layer, and the popliteus

muscle, the flexor digitorum longus, the flexor hallucis longus and the tibialis posterior muscles forming the deep layer.

Anterior muscles of the leg

The tibialis anterior muscle (m. tibiális postérior) is situated on the anterolateral side of the leg. It originates on the lateral condyle, the lateral upper half of the body of the tibia, the upper part of the interosseous membrane and on the crural fascia. On the distal third of the leg the venter of this muscle continues into a long tendon, which passes under the extensor retinacula, in front of the talocrural joint, and is inserted into the plantar surface of the medial cuneiform and the base of the first metatarsal bones.

F u n c t i o n: This muscle dorsiflexes (extends) and inverts (supinates) the foot, raising its medial edge. When the foot is fixed, it can bend the leg forward, as well as help support it in a vertical position.

I n n e r v a t i o n: deep peroneal nerve.

B l o o d   s u p p l y: anterior tibial artery.

The extensor digitorum longus muscle (m. exténsor digitórum lóngus) originates from the lateral condyle of tibia, on the anterior surface of fibula, the upper part of the interosseous membrane and the crural fascia and anterior intermuscular septum. The muscle passes underneath the extensor retinacula, onto the dorsal surface of the foot. At the level of the talocrural joint it divides into four tendons, which are inserted into the bases of the middle and distal phalanges of toes II–V.

Sometimes **a third peroneal muscle (m. peronéus tértius)** separates from the distal part of this muscle and is inserted into the base of the V metatarsal bone.

F u n c t i o n: The extensor digitorum longus extends toes II–V in the metatarsophalangeal joints. It also dorsiflexes the foot in the talocrural joint. When the foot is fixed it supports the leg in a vertical position. The third peroneal muscle participates in lifting the lateral edge of the foot.

I n n e r v a t i o n: deep peroneal nerve.

B l o o d   s u p p l y: anterior tibial artery.

The extensor hallucis longus muscle (m. exténsor hállucis lóngus) is situated between the tibialis anterior muscle and the extensor digitorum longus, and is partially covered by them in the front. It originates from the middle third of tibia and the interosseous membrane of leg. Its tendon passes under the extensor retinaculum and is inserted into the distal phalanx of the great toe.

F u n c t i o n: It extends the great toe and participates in dorsiflexion of the foot.

Innervation: deep peroneal nerve.
Blood supply: anterior tibial artery.

Lateral muscles of the leg

The peroneus longus muscle (m. peronéus lóngus) is situated superficially on the lateral region of the leg. It originates from the upper lateral two thirds of the fibula, lateral condyle of the fibula and the crural fascia. Its tendon curves around the back of the lateral malleolus and passes through its groove of the calcaneus. On the sole this tendon stretches obliquely forward and medial and passes through a homonymous groove on to the cuboid bone. It is inserted into the plantar surface of the medial cuneiform and bases of first and second metatarsal bones.

Function: It plantar flexes the foot, and inverts it, raising its lateral edge.

Innervation: superficial peroneal nerve.

Blood supply: peroneal artery, inferior lateral genicular artery.

The peroneus brevis muscle (m. peronéus brévis) originates on the lower lateral part of the fibula and from the intermuscular septa of the leg. Its tendon curves around the back of the lateral malleolus, passes beneath the retinaculum of the peroneal muscles and onto the foot. It passes along the lateral side of the calcaneus and is inserted into the base of the fifth metatarsal bone.

Function: It lifts the lateral edge of the foot, thus inverting it, and plantar flexes the foot.

Innervation: superficial peroneal nerve.

Blood supply: peroneal artery.

Posterior muscles of the leg

Superficial layer

The triceps surae muscle (m. tríceps súrae) consists of the gastrocnemius and soleus muscles. The gastrocnemius muscle (m. gastrocnémius) has a lateral and a medial heads. The lateral head originates from the lateral side of the distal epiphysis of femur and the lateral condyle. The medial head originates on the medial condyle of the femur. At midlevel of the calf the two heads unite and form the thick calcaneal tendon, which, together with the tendon of the soleus, is inserted into the calcaneal tuberosity.

The **s o l e u s   m u s c l e (m. sóleus)** is covered from behind by the gastrocnemius muscle. It originates from the soleus line of tibia and on the tendinous arch between the leg bones.

F u n c t i o n: The triceps surae muscle flexes the leg and the plantar flexes the foot. When the foot is fixed it supports the leg in a vertical position.

I n n e r v a t i o n: tibial nerve.

B l o o d   s u p p l y: posterior tibial artery.

The plantaris muscle (m. plantáris) is small; it originates from the lateral epicondyle of femur and the oblique popliteal ligament. Its long thin tendon passes between the gastrocnemius and soleus muscles, joins the calcaneal tendon on its medial side and is inserted into the calcaneal tuberosity.

F u n c t i o n: It stretches the capsule of the knee joint and takes part in flexion of the leg and foot.

I n n e r v a t i o n: posterior tibial nerve.

B l o o d   s u p p l y: posterior tibial artery.

Deep layer of the posterior group of the leg muscles

The popliteus muscle (m. poplíteus) is situated in the popliteal fossa. It originates from the outer surface of the lateral condyle of the femur and is inserted into the back of the tibia, above the soleus line.

F u n c t i o n: It flexes and pronates the leg, and stretches the capsule of the knee joint, preventing its synovial membrane from being damaged.

I n n e r v a t i o n: tibial nerve.

B l o o d   s u p p l y: popliteal artery.

The flexor digitorum longus muscle (m. fléxor digitórum lóngus) is situated behind and medial of the posterior tibial muscle. It originates from the back of tibia, beneath the soleus line, on the crural fascia and the posterior intermuscular septa. Its tendon stretches downward, crosses the tendon of the posterior tibial muscle and passes behind the medial malleolus beneath the flexor retinaculum. Then it curves around the sustentaculum tali of calcaneus, divides into four separate tendons, which are inserted into the distal phalanges of toes II–V.

F u n c t i o n: Flexion of distal phalanges of toes II–V. Plantar flexion and inversion (supination) of the foot.

I n n e r v a t i o n: tibial nerve.

B l o o d   s u p p l y: posterior tibial artery.

The flexor hallucis longus muscle (m. fléxor hállucis lóngus) originates on the lower two thirds of fibula, the interosseous membrane of leg

and the posterior intermuscular septum. This muscle passes behind and lateraliy of the tibialis posterior muscle. Its tendon passes underneath the flexor retinaculum behind the medial malleolus and lateral of the tendon of the long flexor of toes. It passes under the sustentaculum tali and is inserted into the base of the distal phalanx of the great toe.

F u n c t i o n: It flexes the great toe and takes part in inversion of the foot.

I n n e r v a t i o n: posterior tibial artery, peroneal artery.

B l o o d s u p p l y: posterior tibial artery.

The tibialis posterior muscle (m. tibiális postérior) is situated between the flexor digitorum longus and the flexor hallucis longus. It originates from the back of fibula, the inferior surface of the lateral condyle and the upper two thirds of tibia, and on the interosseous membrane of the leg. The tendon of this muscle passes along the back of the medial malleolus, onto the plantar surface of the foot. It is inserted into the tuberosity of the navicular bone, all three cuneiform bones and into the base of the fourth metatarsal bone.

F u n c t i o n: It plantar flexes and inverts the foot.

I n n e r v a t i o n: tibial nerve.

B l o o d s u p p l y: posterior tibial artery.

Muscles of the foot

Muscles of this group originate from and are inserted within the limits of the foot, that is, into the dorsal and plantar surfaces of tarsal and metatarsal bones and phalanges. The dorsal group of muscles includes the extensor hallucis brevis and the extensor digitorum brevis (Fig. 114). The muscles of the plantar side are divided into the lateral, middle and the medial groups. The medial group includes the abductor hallucis muscle, the flexor hallucis brevis and the adductor hallucis. The middle group consists of four lumbricals and seven interossei muscles, the flexor digitorum brevis and the quadratus plantae muscles. The lateral group includes the abductor digiti minimi, the flexor digiti minimi brevis, opponens digiti minimi muscles.

Dorsal muscles of the foot

The extensor digitorum brevis (m. exténsor digitórum brévis) is a small muscle, which originates on the anterior part of the upper and lateral surfaces of calcaneus. It stretches obliquely forward and medially and divides into three tendons, which join the tendons of the extensor digitorum longus and are inserted into bases of middle and distal phalanges.
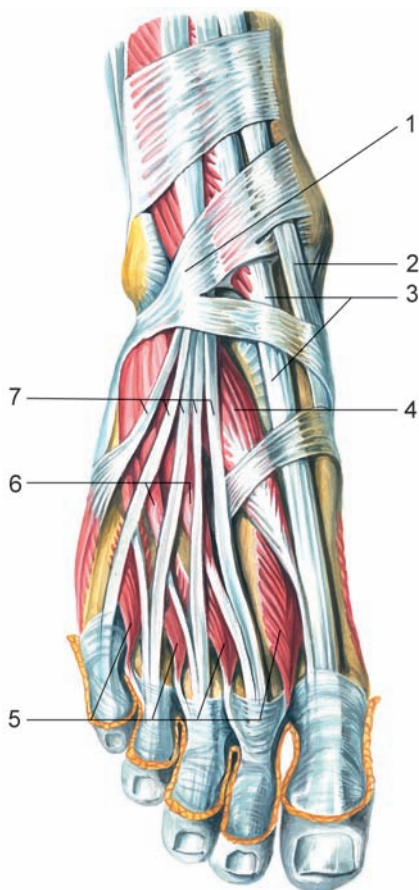
Fig. 114. Tendons of extensors and short muscles of dorsum of foot.

1 — inferior extensor retinaculum; 2 — tendon of tibialis anterior; 3 — tendon of extensor hallucis longus; 4 — extensor hallucis brevis; 5 — interossei dorsales; 6 — extensor digitorum brevis; 7 — tendons of extensor digitorum longus.

F u n c t i o n: extension of the toes.

I n n e r v a t i o n: deep peroneal nerve.

B l o o d   s u p p l y: lateral tarsal artery, peroneal artery.

The extensor hallucis brevis (m. extensor hallucis brevis) is situated to the medial of the extensor digitorum brevis. It originates from the superior surface of calcaneus, stretches forward and medially, and is inserted with a narrow tendon into top of the base of the proximal phalanx of great toe.

F u n c t i o n: extension of the great toe.

I n n e r v a t i o n: deep peroneal nerve.

B l o o d   s u p p l y: dorsal artery of foot.

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Medial group of the muscles of the sole

The abductor hallucis muscle (m. abdúctor hállucis) originates from the medial surface of the calcaneal tuberosity and the plantar aponeurosis. It stretches along the medial edge of the foot and is inserted from the medial side into the base of the proximal phalanx of great toe (Fig.115).

F u n c t i o n: abduction of the great toe.

I n n e r v a t i o n: medial plantar nerve.

B l o o d s u p p l y: medial plantar artery.

The flexor hallucis brevis (m. fléxor hállucis brévis) originates from the medial side of the plantar surface of the cuboid and cuneiform bones. Its tendon is inserted into the proximal phalanx of the great toe and the sesamoid bone, located near the first metatarsophalangeal joint.

F u n c t i o n: flexion of the great toe.

I n n e r v a t i o n: medial and lateral plantar nerves.

B l o o d s u p p l y: medial plantar artery, deep plantar arch.

The adductor hallucis muscle (m. addúctor hállucis) has an o b l i q u e and a t r a n s v e r s e h e a d s. The oblique head originates on the cuboid and lateral cuneiform bones, bases of II–IV metatarsals and the tendon of the long peroneal muscle. Its venter stretches forward and medially and unites with the transverse head, forming a common tendon. The transverse head originates as a narrow muscle strap on capsules of the III–V metatarsophalangeal joints. The common tendon of the muscle is inserted into the base of the proximal phalanx of great toe and the lateral sesamoid bone.

F u n c t i o n: it adducts the great toe and participates in its flexion.

I n n e r v a t i o n: lateral plantar nerve.

B l o o d s u p p l y: deep plantar arch.

Lateral group of muscles of the sole

The abductor digiti minimi muscle (m. abdúctor dígiti mínimi) originates from the bottom of the calcaneal protuberance, tuberosity of the fifth metatarsal and the plantar aponeurosis. Its tendon passes along the lateral side of the foot and inserts into the lateral side of the proximal phalanx of the little toe.

F u n c t i o n: it flexes the proximal phalanx of the little toe and adducts it.

B l o o d s u p p l y: lateral plantar artery.

The flexor digiti minimi brevis (m. fléxor dígiti mínimi brévis) originates from the medial plantar surface of the fifth metatarsal bone and
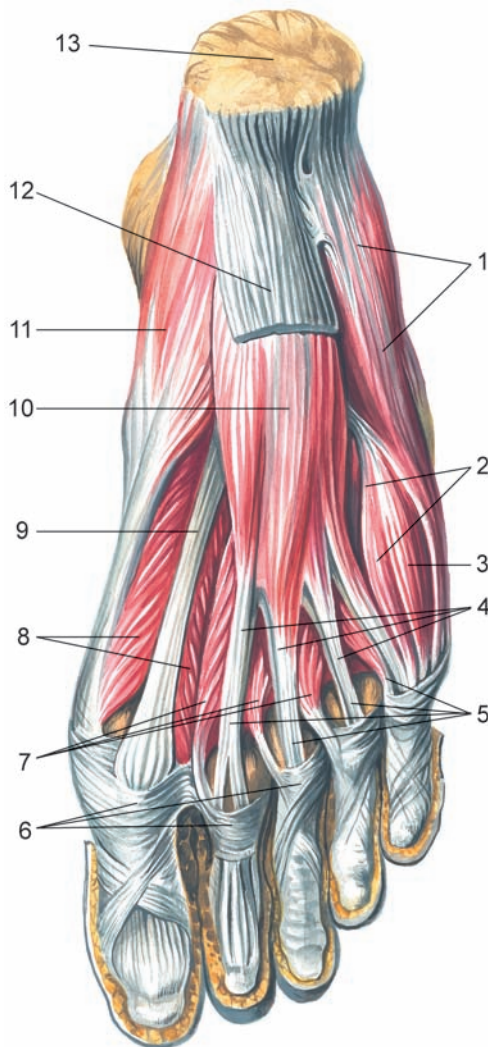
Fig. 115. Muscle of foot, right. Plantar surface.

1 — abductor digiti minimi; 2 — plantar interossei; 3 — flexor digiti minimi brevis; 4 — tendon of flexor digitorum longus; 5 — tendons of flexor digitorum brevis; 6 — fibrous sheaths of digits of foot; 7 — lumbricals; 8 — tendon of flexor hallucis longus; 9 — tendon of flexor hallucis longus; 10 — flexor digitorum brevis; 11 — abductor hallucis; 12 — plantar aponeurosis (cut off); 13 — calcaneus.

the plantar ligament. Its tendon is inserted into the base of the proximal phalanx of little toe.

F u n c t i o n: flexion of the little toe.

I n n e r v a t i o n: lateral plantar nerve.

B l o o d   s u p p l y: lateral plantar artery.

Middle group of the muscles of the sole

The flexor digitorum brevis (m. fléxor digitórum brévis) is situated beneath the plantar aponeurosis, between the abductor hallucis muscle and the abductor digiti minimi muscle. Beneath this muscle lies the quadratus plantae muscle and tendons of the flexor digitorum longus. The flexor digitorum brevis originates from the bottom of the calcaneal tuberosity and on the plantar aponeurosis. It divides into four tendons, which are inserted into the middle phalanges of toes II–V. At the level of the proximal phalanges each tendon splits into two fascicles, beneath which pass the tendons of the flexor digitorum longus. Part of the tendinous fascicles of the flexor digitorum brevis weaves into the fibrous sheaths of toes.

F u n c t i o n: Flexion of toes II–V.

I n n e r v a t i o n: medial plantar nerve.

B l o o d s u p p l y: lateral and medial plantar arteries.

The quadratus plantae muscle (m. quadrátus plántae) has a medial and a lateral heads. The l a t e r a l h e a d originates from the lateral bottom surface of the calcaneus and the lateral edge of the long plantar ligament. The m e d i a l h e a d originates from the medial bottom surface of calcaneus and the medial edge of the long plantar ligament. The two heads unite into a flattened muscle, which is inserted at midlevel of the sole into the tendons of the long flexor of the toes.

F u n c t i o n: It plantar flexes the foot and directs the pull of the long flexor of toes.

I n n e r v a t i o n: lateral plantar nerve.

B l o o d s u p p l y: lateral plantar artery.

The lumbricals muscles (m. lumbricáles) are four thin fusiform muscles, situated between distal parts of the tendons of the long flexor of the toes. The lateral three of these muscles originate with two heads on adjacent sides of tendons. The medialmost lumbrical originates with only one head on the medial side of the tendon of second toe. Each lumbrical is inserted into the medial edges of the proximal phalanges of toes II–V.

F u n c t i o n: They flex the proximal phalanges and extend the middle and distal phalanges of toes II–V, abducting them away from the great toe.

I n n e r v a t i o n: medial and lateral plantar nerves.

B l o o d s u p p l y: medial and lateral plantar arteries.

The plantar (3) and dorsal (4) interossei muscles (mm. interóssei dorsáles et plantáres) are thin muscles, situated deep in the spaces between the metatarsal bones. The plantar interossei muscles originate from the bases and medial surfaces of the III–V metatarsals. The dorsal interossei muscles originate with two heads from the adjacent surfaces of the metatarsal bones. The plantar muscles insert on medial surfaces of bases of proximal phalanges

of toes III–V. The dorsal muscles are inserted into bases of the proximal phalanges and to tendons of the long extensor of toes. The first interosseous muscle is inserted into the medial side of the second toe, while the second to fourth muscles are inserted into lateral sides of toes II–V.

F u n c t i o n: Plantar muscles adduct toes III–V towards the second toe and flex the proximal phalanges. The dorsal muscles abduct toes II–IV and flex the proximal phalanges (table 15).

I n n e r v a t i o n: lateral plantar nerve.

B l o o d s u p p l y: plantar arch, plantar metatarsal arteries.

Questions for revision and examination

1. Into what groups are muscles of the leg divided? Name the muscles of each group.
2. Name the muscle of the dorsal side of the foot. Where do they originate from and where are they inserted into?
3. Into what groups are muscles of the sole divided? Name the muscles of each group.

Table 15. Muscles of the lower extremities.

Muscle	Origin	Insertion	Action	Innervation
I. Muscles of the pelvis. Internal group of muscles:				
Iliopsoas: Iliac	Iliac fossa of ilium			
Psoas major	Lateral surfaces of the bodies and intervertebral disks, and transverse processes of T12 and L1-L5 vertebrae	A common tendon is inserted into the lesser trochanter of femur	Flexion of thigh in the coxal joint. When lower limb is fixated it bends the pelvis together with the trunk	Muscular branches of the lumbar plexus
Obturator internus	Borders of the obturator foramen and obturator membrane	Medial surface of the greater trochanter of femur	Turns the thigh laterally	Muscular branches of sacral plexus
Piriformis	Pelvic surface of sacrum, lateral of the sacral foramina	Apex of the greater trochanter	Same as above	Same as above
External muscles:				
Gluteus maximus	Gluteal surface of ilium, dorsal surfaces of sacrum and coccyx	Gluteal tuberosity of femur and iliotibial tract	Extension of thigh. When lower extremities are fixated it straightens body and steadies the pelvis and trunk	Inferior gluteal nerve

Gluteus medius	Gluteal surface of ilium	Apex and lateral surface of the greater trochanter	Abducts the thigh; its anterior fascicles rotate femur medially; posterior fascicles rotate femur laterally	Superior gluteal nerve
Gluteus minimus	Gluteal surface of ilium	Anterolateral surface of the greater trochanter	Same as above	Same as above
Quadratus femoris	Lateral border of ischial tuberosity	Intertrochanteric crest	Turns the thigh laterally	Muscular branches of sacral plexus
Obturator externus	External surfaces of pubis and ischium, around the obturator foramen; obturator membrane	Trochanteric fossa of femur	Same as above	Obturator nerve
Tensor of fascia lata	Superior anterior iliac spine	Continues into the fascia lata of the thigh (iliotibial tract)	Stretches the fascia lata	Superior gluteal nerve
Superior and inferior gemellus muscles	Iliac spine, ischial tuberosity	Trochanteric fossa of femur	Turn the thigh laterally	Muscular branches of the sacral plexus
II. Muscles of the free lower extremity Muscles of the thigh Anterior group:				
Sartorius	Superior anterior iliac spine	Tuberosity of tibia, deep fascia of thigh	Flexes the femur and leg; turns the thigh laterally	Femoral nerve
Quadriceps femoris: Vastus lateralis	Intertrochanteric line, greater trochanter, lateral labrum of linea aspera of femur and lateral intermuscular septum of thigh	Base and lateral borders of the patella and tuberosity of tibia	Extends the leg in the knee joint	Same as above
Vastus medialis	Medial labrum of linea aspera and medial intermuscular septum			
Vastus intermedius	Anterior and lateral surfaces of femur, and lateral intermuscular septum of thigh			
Rectus femoris	Inferior anterior iliac spine			

Posterior group:				
Biceps femoris: Long head Short head	Ischial tuberosity Lateral lip of linea aspera, lateral epicondyle, lateral intermuscular septum of thigh	A common tendon inserts on the head of fibula, lateral condyle of tibia and deep crural fascia	Flexes the leg. When the latter is flexed it rotates it laterally; long head extends femur in the hip joint	Long head — tibial nerve; short head — common peroneal nerve
Semitendinosus	Ischial tuberosity	Medial part of the tuberosity of tibia, deep crural fascia	Extension of thigh, flexion of leg. When leg is fixed it is rotated laterally	Tibial nerve
Semimembra-nosus	Ischial tuberosity	Medial condyle of tibia	Extension of thigh, flexion of leg. When leg is fixed it is rotated laterally	Same as above
Medial group:				
Gracilis	Inferior ramus of pubis	Medial surface of tibia	Adduction of thigh and flexion of leg; when leg is bent it rotates it medially	Obturator nerve
Pectineus	Superior ramus of pubis and pubic crest	Medial lip of linea aspera and pectineal line of femur	Adduction and flexion of thigh	Same as above
Adductor longus	Superior ramus of pubis	Medial lip of linea aspera of femur	Adduction, flexion and lateral rotation of thigh	Same as above
Adductor brevis	Inferior ramus and body of pubis	Medial lip of linea aspera of femur	Adduction and flexion of thigh	Same as above
Adductor magnus	Ramus of ischium and ischial tuberosity	Medial lip of linea aspera of femur	Adduction and lateral rotation of thigh	Obturator and sciatic nerves
Muscles of the leg Posterior group:				
Triceps surae: Gastrocnemius Lateral head Medial head Soleus	Femur, above lateral condyle Femur, above medial condyle Posterior surface of tibia, tendinous	A common tendon (Achilles' tendon) inserts on the calcaneal tuber	Flexion of the leg and foot Plantar flexion of the foot	Tibial nerve

	arch between tibia and fibula			
Plantaris	Lateral epicondyle of femur and capsule of knee joint	Into the Achilles' tendon	Plantar flexes the foot and stretches the capsule of the knee joint	Same as above
Popliteus	Same as above	Posterior surface of tibia	Flexion of the leg	Same as above
Flexor digitorum longus	Posterior surface of tibia, deep crural fascia	Plantar surface of distal phalanges of toes II–V	Flexion of toes II–V and plantar flexion of the foot	Same as above
Tibialis posterior	Posterior surface of tibia, medial surface of fibula, interosseous membrane of leg	Tuberosity of navicular bone, plantar surfaces of cuneiform and fourth metacarpal bones	Flexion, adduction and supination of the foot	Same as above
Flexor hallucis longus	Posterior surface of fibula, interosseous membrane and posterior intermuscular septum of leg	Plantar surface of the distal phalanx of great toe	Flexion of the great toe and adduction of the foot	Same as above
Anterior group:				
Tibialis anteroir	Lateral condyle and lateral surface of tibia; interosseous membrane of leg	Medial cuneiform and base of first metatarsal	Extension and supination of the foot; when the foot is fixed it bends the leg forward	Deep peroneal nerve
Extensor digitorum longus	Lateral condyle of tibia, medial surface of fibula and interosseous membrane of leg	Tendinous aponeurosis of dorsal surface of toes II–V	Extension of toes II–V and of the foot	Same as above
Extensor hallucis longus	Medial surface of fibula and interosseous membrane	Tendinous aponeurosis of the dorsal surface of great toe	Extension of the great toe and foot	Same as above
Lateral group:				
Peroneus longus	Head and lateral surface of fibula, lateral condyle of tibia	Plantar surface of the medial cuneiform bone and I–II metatarsals	Flexion of the foot, raising of its lateral edge and support of the transverse arch	Superficial peroneal nerve

Peroneus brevis	Lateral surface of fibula	Tuberosity of fifth metatarsal bone	Flexion of the foot and lifting of its lateral edge	Same as above
Muscles of the foot **Dorsal muscles:**				
Extensor digitorum brevis	Dorsal surface of calcaneus	Dorsal tendinous aponeurosis of toes II–V	Extends toes II–V	Deep peroneal nerve
Extensor hallucis brevis	Dorsal surface of calcaneus	Dorsal surface of great toe	Extends the great toe	Same as above
Plantar muscles **Medial group:**				
Abductor hallucis	Medial side of calcaneal tuber	Proximal phalanx of great toe	Abduction of the great toe	Medial plantar nerve
Flexor hallucis brevis	Plantar surface of cuneiform and cuboid bones	Proximal phalanx of the great toe; sesamoid bone	Flexion of the great toe	Same as above
Adductor hallucis	Oblique head—cuboid, lateral cuneiform, bases of II–V metatarsals; transverse head—capsule of II–V metatarso-pha-langeal joints	Base of the prox-imal phalanx of great toe and lat-eral sesamoid bone	Adduction and flexion of great toes; support of the transverse arch of the foot (transverse head)	Lateral plantar nerve
Lateral group:				
Abductor digiti minimi	Calcaneus and V metatarsal bone	Proximal phalanx of little toe	Abduction and flexion of the proximal phalanx of little toe	Lateral plantar nerve
Flexor digiti mini-mi brevis	Fifth metatarsal bone	Base of the proxi-mal phalanx of lit-tle toe	Flexion of the little toe	Same as above
Middle group:				
Flexor digitorum brevis	Plantar surface of calcaneal tuber	Middle phalan-ges of toes II–V	Flexion of toes II–V and support of the longitudi-nal arches of the foot	Medial plantar nerve
Quadratus plantae	Plantar surface of calcaneus	Lateral borders of tendons of long flexor of toes	Flexion of toes	Lateral plantar nerve
Lumbricals (4)	Tendons of the	Medial borders of proximal pha-	Flexion of proxi-mal phalanges	Medial and lateral plantar nerves

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	long flexor of toes	langes, dorsal aponeurosis of toes II–V	and extension of middle phalanges of toes	
Plantar (3) and dorsal (4) interossei	Plantar—medial surface of III–IV metatarsal bones; dorsal—adjacent surfaces of metatarsal bones	Bases of proximal phalanges of corresponding toes	Plantar — adduction of toes III and IV to second toe, flexion of proximal phalanges; dorsal—abduction of toes II-IV and adduction of II toe (first muscle), flexion of proximal phalanges	Lateral plantar nerve

FASCIAE, SYNOVIAL BURSAE AND SHEATHS
OF THE LOWER EXTREMITY

Many muscles, being inserted into the lower extremities actually originate from the vertebral column and bones of the pelvis. Consequently, the fasciae of these muscles are connected with fasciae, which line the pelvis and the abdominal cavity. The l u m b a r   f a s c i a (fáscia lumbális) is a continuation of the intra-abdominal fascia. It covers the major psoas muscle. Its lateral end attaches to the intervertebral disks, bodies of lumbar vertebrae, and the upper part of sacrum. The lateral end connects with the fascia of the lumbar quadrate muscle. At the bottom the lumbar fascia continues into the iliac fascia. The i l i a c   f a s c i a (fáscia iliáca) covers the iliac muscle and attaches to the internal lip of the iliac crest, the arcuate line of ilium and the pubic tubercle. The iliac fascia accretes with the inguinal ligament. From there it stretches over to the iliopubic eminence, forming the i l i o p e c t i n e a l   a r c h (árcus iliopéctineus). This arch divides the space beneath the inguinal ligament into two spaces (lacunae). The medial of these is the v a s c u l a r   s p a c e, and the lateral is the m u s - c u l a r   s p a c e. **The g l u t e a l   f a s c i a (fáscia gluteális)** covers the gluteus maximus muscle. This fascia originates from the dorsal surface of the sacrum and the external lip of the iliac crest. Its deep lamina separates the gluteus maximus muscle from the gluteus medius and tensor muscle of fascia lata. The thin superficial lamina of the gluteal fascia forms part of the superficial fascial of the body.

The f a s c i a   l a t a (fáscia láta) forms a thick sheath for muscles of the thigh. At the top it attaches to the iliac crest, the inguinal ligament, the pubic symphysis and the ischial bone. In the back it continues into the gluteal fascia. In the proximal front region of the thigh the fascia lata has a superficial and a deep laminae. The s u p e r f i c i a l   l a m i n a

covers the superficial front muscles of the thigh, including the sartorius muscle, rectus muscle, and the adductor muscles of thigh. Beneath the inguinal ligament the superficial lamina has an oval thinning region called the h i a t u s s a p h e n u s, through which the great saphenous vein enters the femoral vein. The hiatus saphenus is covered by the c r i b r i f o r m f a s c i a (f á s c i a c r i b r ó s a), which has a large number of foramina. At the top, bottom and lateral side the hiatus saphenus is bordered by a thickened region of the fascia lata called the «falciform margin». The d e e p l a m i n a, which covers the pectineal muscle and the distal part of the iliopsoas muscle, is called the iliopectineal fascia.

The fascia lata gives off intermuscular septa towards the femur, which form fascial sheaths for the muscles of this region. The l a t e r a l i n t e r - m u s c u l a r s e p t u m attaches to the lateral labium of the linea aspera, and separates the quadriceps muscle from the posterior group of muscle of the thigh. The m e d i a l i n t e r m u s c u l a r s e p t u m attaches on the medial labium of the linea aspera. It separates the quadriceps femoris from the medial (adductor) muscles of the thigh.

The thickest part of the fascia lata is located on the lateral side of the thigh, where it forms **the iliotibial tract (tráctus iliotibiá- lis)**. This tract serves as the tendon of the tensor muscle of the fascia lata and part of the gluteus maximus muscle. At the bottom the fascia lata continues into the crural fascia. In the back it also forms the popliteal fascia, which covers the popliteal fossa.

The deep fascia of leg or **c r u r a l f a s c i a (f á s c i a c r ú r i s)** forms a sheath for the muscles of the leg and serves as a point of origin of some of them. This fascia accretes with the periosteum on the anterior margin of tibia and gives off two intermuscular septa toward the fibula. The a n t e r i - o r i n t e r m u s c u l a r s e p t u m of the leg separates the peroneal muscles from the anterior group of leg muscles. The p o s t e r i o r i n t e r m u s c u - l a r s e p t u m of the leg separates the lateral and posterior groups of muscles. On the back of the leg the crural fascia has two laminae. The deep lamina separates the triceps muscle of the calf from the posterior tibial muscle and the long flexor muscles.

At the level of bases of the malleoli the crural fascia is strengthened by transverse fibers, which form the retinacula of tendons. The s u p e r i o r e x t e n s o r r e t i n a c u l u m is stretched between the medial and lateral malleoli. The i n f e r i o r e x t e n s o r r e t i n a c u l u m is situated where the crural fascia passes into the fascia of the dorsal side of the foot. The inferior retinaculum begins on the lateral surface of the calcaneus, below the apex of the lateral malleolus and divides into two parts. The superior part is attached to the front of the medial malleolus, while the inferior part stretches to the medial edge of the foot and attaches to the navicular and

medial cuneiform bones. The inferior retinaculum gives off connective tissue septa, which form three fibrous tunnels. Situated in these tunnels are synovial sheaths of the extensor tendons. The medial tunnel contains the tendon sheath of tibialis anterior muscle. This sheath extends from the top of the superior extensor retinaculum to the apex of the medial malleolus. The second fibrous tunnel contains the tendon sheath of the extensor hallucis longus. The third tunnel contains the tendon sheath of the extensor digitorum longus. Both these sheaths extend beyond the distal edge of the inferior extensor retinaculum, ending at the level of the bases of the metatarsal bones. In the back of the synovial sheaths of extensor muscles, in a separate tunnel the dorsal artery and vein of the foot and the deep peroneal nerve pass.

Behind the medial malleolus the crural fascia has a thickening, which forms the f l e x o r r e t i n a c u l u m. This retinaculum stretches between the medial malleolus and the medial surface of the calcaneus. Beneath this retinaculum are three fibrous tunnels. The anterior tunnel, which is situated directly behind the medial malleolus, contains the tendon sheath of the tibialis posterior muscle. The second tunnel, situated behind and lateral of the first, contains the tendon sheath of the flexor digitorum longus. The posterior tunnel contains the tendon sheath of the flexor hallucis longus. This sheath lies directly behind the articular capsule of the talocrural joint, and often communicates with its cavity. The tendon sheaths of the flexor digitorum longus and the flexor hallucis longus are sometimes also communicates. Between the tunnels of the long flexor muscles there is another fibrous tunnel, which contains the posterior tibial artery and veins and the tibial nerve. On the back of the talocrural joint the proper fascia forms a tendon sheath of the Achilles' tendon.

Along the whole length between the metatarsal bones and the distal phalanges the tendons of the flexor digitorum longus and the flexor hallucis longus are contained within separate short synovial sheaths.

Behind and below the lateral malleolus the crural fascia forms two retinacula for the peroneal muscles. The s u p e r i o r p e r o n e a l r e t i n a c u l u m stretches between the lateral malleolus and the calcaneus. Beneath this retinaculum is a common synovial sheath of the peroneal muscles. Somewhat lower, on the lateral surface of calcaneus, is the i n f e r i o r p e r o n e a l r e t i n a c u l u m. When passing under this retinaculum, the common tendon sheath of the peroneal muscles splits into two parts, which continue separately along each tendon. The sheath of the short peroneal muscle ends at the lower edge of the inferior peroneal retinaculum. The tendon sheath of the long peroneal muscle extends to the plantar surface of calcaneus. On the sole this tendon has a separate sheath, which

extends from the groove on the cuboid bone to its point of insertion on bases of I and II metatarsals and the medial cuboid bone.

The **dorsal fascia of the foot (fáscia dorsális pédis)** is weakly developed. It has superficial and deep laminae, between which lie the tendons of the long and short extensors of toes, as well as nerves and blood vessels.

The plantar fascia of the foot also has the superficial and deep laminae. The superficial lamina forms the thick **plantar aponeurosis (aponeurósis plantáris)**. This aponeurosis is a thick fibrous plate, situated directly beneath the skin of the sole. It begins on the calcaneus, broadens towards the front and splits into five fascicles, which are attached to the fibrous sheaths of the toes. Near the heads of the metatarsal bones transverse fascicles form the superficial transverse metatarsal ligament. The plantar aponeurosis is tightly accreted with the short flexor of the toes. Different groups of muscles of the sole are separated by the medial and lateral intermuscular septa, which stretch from the edges of the plantar aponeurosis. The deep lamina of the plantar fascia covers the plantar interosseous muscles, and is called the plantar interosseous fascia.

Questions for revision and examination

1. Name the fasciae of the lower extremity. Where are they situated, and what muscles do they cover?

2. Name the retinacula of the leg and foot. Where are they situated, and which tendons pass beneath them?

3. Describe the location of the synovial tendon sheaths of the flexor and extensor muscles of the toes.

TOPOGRAPHIC ANATOMY AND FATTY TISSUE SPACES OF THE LOWER EXTREMITY

Among surface structures of the gluteal region one can see prominences of the muscles, the gluteal cleft and the gluteal fold. Deep in the medial side of this fold it is possible to palpate the ischial tuberosity. In very thin people, visible on the front of the hip, are the inguinal fold and the borders of the femoral triangle. The contours of the quadriceps muscle of the thigh are also relatively prominent. On the knee it is possible to palpate the patella and, at its sides, the condyles of the femur and tibia. On the back of the knee is the popliteal fossa. Visible on the front of the leg is the anterior crest of the tibia. On the posterior surface of the leg are the contours of the gastrocnemius muscle and the calcaneal (Achilles) tendon. At either side of the talocrural joint it is possible to see the lateral and medial malleoli.

The skin of the buttocks, of the front surface of the knee and of the sole of the foot is thick, while on the thigh, the back of the knee, the leg and the dorsal side of the foot the skin is thin and movable. Through the subcutaneous tissue of the medial leg surface the great saphenous vein and the saphenous nerve pass. The subcutaneous tissue of the posterior leg surface contains the small saphenous vein. Subcutaneous tissue is best developed on the buttocks, from where it continues onto the lumbar region, forming the lumbogluteal adipose accumulation.

The sacrotuberal and sacrospinous ligaments and the greater sciatic notch form the g r e a t e r s c i a t i c f o r a m e n. This foramen is divided by the piriform muscle into the s u p r a p i r i f o r m (f o r á m e n s u p r a - p i r i f ó r m e) and i n f r a p i r i f o r m (f o r á m e n i n f r a p i r i f ó r m e) foramina. Both these foramina serve as passages for blood vessels and nerves.

On the front of the thigh the iliolumbar fascia accretes with the lateral part of the inguinal ligaments. The medial part of this fascia continues from the inguinal ligament onto the thigh, together with the iliolumbar muscle. On the thigh it connects with the pectineal fascia. Part of the fascicles of the iliolumbar fascia stretches from the inguinal ligament to the pubic crest (medial of the iliolumbar muscle), forming the i l i o p e c t i n e a l a r c h. This arch separates the muscular and vascular lacunae, or compartments. The m u s c u l a r c o m p a r t m e n t is occupied by the iliolumbar muscle and the femoral nerve. Through the v a s c u l a r c o m p a r t m e n t the femoral artery and vein pass.

In the medial part of the vascular compartment, between the inguinal ligament and the pubic crest, the d e e p f e m o r a l r i n g (á n u l u s f e - m o r á l i s p r o f ú n d u s) of the femoral canal is situated. This canal sometimes becomes an outlet for a femoral hernia. The f e m o r a l c a n a l (c a n á l i s f e m o r á l i s) is 1–3 cm long and has three walls. Its lateral wall is formed by the femoral vein; the anterior wall — by the falciform margin and superior cornu of the fascia lata; the posterior fall is formed by the deep lamina of fascia lata. The s a p h e n o u s r i n g (á n u l u s s a p h é n u s) of the femoral canal is bordered laterally by the falciform margin of the fascia lata and is covered by the cribriform fascia. The deep femoral ring contains a small amount of loose connective tissue and the lymph node of Piragoff-Rosenmoller. This ring has four walls, formed by the inguinal ligament, the femoral vein, the l a c u n a r l i g a m e n t and the p e c t i n e a l l i g a m e n t, which is a thickening of the periosteum in the region of the pubic crest. The lacunar ligament is formed by connective tissue fibers stretched between the medial end of the inguinal ligament laterally and to the back, along the superior ramus of pubis. These fibers form a curve in the sharp angle between inguinal ligament and the pubic bone.

The f e m o r a l   t r i a n g l e, situated on the front of the thigh, is bordered by the long adductor muscle, the sartorius muscle and the inguinal ligament. Through this triangle, beneath the superficial lamina of the fascia lata, passes the i l i o p e c t i n e a l   g r o o v e (s ú l c u s   i l i o p e c t i n e u s), bordered on the sides by the iliopsoas and pectineal muscles. Through this groove, covered by the deep lamina of the fascia lata, pass the femoral artery and vein. At the bottom this groove continues into **the adductor (Hunter's) canal (canális adductórius)**, which contains the femoral artery and vein, and the saphenous nerve. The medial vastus muscle and the great adductor muscle form the lateral and medial walls of the adductor canal. The anterior wall is formed by the fibrous «adductor» lamina, stretched between the aforementioned muscles. This lamina has a tendinous hiatus opening, through which the saphenous nerve and the descending genicular artery exit the canal. The tendon of the adductor magnus muscle and the femur forms the inferior opening of the femoral canal. It opens into the popliteal fossa and serves as an exit for the femoral artery and vein.

In the anterior region of the knee, beneath the skin and fascia, there are several synovial bursae. Between the laminae of the superficial fascia lies the s u b c u t a n e o u s   p r e p a t e l l a r   b u r s a. Beneath the proper fascia lies the s u b f a s c i a l   p r e p a t e l l a r   b u r s a. Somewhat below the patella lie the subcutaneous bursa of tibial tuberosity and the s u b c u - t a n e o u s   i n f r a p a t e l l a r   b u r s a.

The popliteal fossa (fóssa poplítea) is complicated in structure. At the top it is bordered by the tendons of the semitendinosus and semimembranosus muscles on the medial side, and of the biceps on the lateral side. At the bottom it is bordered by the two heads of the gastrocnemius muscle. Beneath the thick popliteal fascia the popliteal fossa is filled by connective tissue. Situated in the connective tissue is a neurovascular bundle, formed by the tibial nerve and the popliteal artery and vein. The popliteal fossa also contains lymph nodes. Its floor is formed by the popliteal surface of femur and the back of the knee joint. This fossa communicates through the femoral canal with the femoral triangle, and at the bottom, through the cruropopliteal canal, with the back of the leg. Through the superior musculoperoneal canal this fossa communicates with the lateral muscle bed of the leg.

The superior musculoperoneal canal (canális musculoperonéus supérior) is situated in the upper part of the lateral osteomuscular bed. It is formed by the two heads of the peroneus longus muscle on the lateral side, and the head of fibula and lateral condyle of tibia on the medial side. This canal contains the common peroneal nerve. **The inferior musculoperoneal canal (canális musculoperonéus inférior)** is situated behind the middle part of the fibula. Its front wall is formed by the fibula, the back wall —

by the flexor hallucis longus and tibialis posterior muscle. This canal contains a section of the peroneal artery, which also passes through the cruropopliteal canal.

The cruropopliteal canal (canális cruropplíteus) is situated in the posterior muscle bed. Its front wall is formed by the posterior surface of the tibia. The back wall is formed by the soleus muscle and its fascia. The lateral wall of the cruropopliteal canal is formed by the flexor hallucis longus, and the medial — by the flexor digitorum longus. The superior opening of the canal is formed by the tendinous arch of the soleus muscle and the popliteus muscle. This opening serves as an entrance for the posterior tibial artery and vein, and the tibial nerve. Through the inferior opening, which is formed by the posterior tibial muscle and the tendon of triceps surae (Achilles' tendon), this neurovascular bundle goes out onto the foot. On the intermuscular septum of the leg is the anterior opening of the cruropopliteal canal, through which the anterior tibial artery passes onto the front of the leg. Approximately 4–5 cm below the entrance of this canal, there is a foramen leading into the inferior musculoperoneal canal.

In the region of the talocrural joint, on its sides are the medial and lateral malleoli. On the front of this joint it is possible to palpate the extensors digitorum and the dorsal artery of the foot. Beneath the skin, above the medial and lateral malleoli, there are often s u b c u t a n e o u s b u r s a e o f t h e m a l l e o l i (subcutaneous bursa of medial malleolus and subcutaneous bursa of lateral malleolus).

The dorsal surface of the foot is covered with the thin movable skin. Located on the front of the medial malleolus is the beginning of the great saphenous vein, situated in the superficial fascia, next to the saphenous nerve. Situated behind the lateral malleolus, next to the sural nerve, is the beginning of the small saphenous vein.

On the medial side of the foot, 3–4 cm to the front of the medial malleolus is the navicular tuberosity. On the lateral edge of the foot it is possible to palpate the tuberosity of the V metatarsal bone. Beneath the apex of the lateral malleolus is the lateral process of the talus.

In the region beneath the medial malleolus, beneath the flexor retinaculum, is a space called the m e d i a l m a l l e o l a r c a n a l. This canal is bordered at the top and front by the medial malleolus and the talus, and at the lateral side — by the calcaneus. In the front it continues into the calcaneal canal, situated between the calcaneus on the medial side, and the abductor hallucis on the lateral. The c a l c a n e a l c a n a l passes into posterior part of the fascial space of the sole.

On the sole of the foot the p l a n t a r a p o n e u r o s i s, which is tightly connected with the skin, gives off intermuscular septa, forming muscle

beds for the medial, lateral and middle groups of muscles. The medial muscle bed contains the adductor and abductor muscles of the great toe, its short flexor, and the medial neurovascular bundle of sole, after it exits from the calcaneal canal.

The middle muscle bed is divided by the deep lamina of the plantar fascia into a superior (deep) and an inferior (superficial) spaces. The deep space contains the interosseous muscles. The superficial space contains the short flexor of toes and the plantar quadrate muscle, as well as the tendons of the long flexor of the toes with the lumbrical muscles. The lateral muscle bed contains the short flexor of little toe and the abductor of little toe.

The lateral neurovascular bundle of the sole passes through the middle fascial muscle bed, between the short flexor of the toes laterally, and the plantar quadrate muscle medially. In the anterior region of this bed the plantar metatarsal artery branches off the lateral plantar artery.

Questions for revision and examination

1. Name the canals of the lower extremity, which contain neurovascular bundles. What forms the walls of these canals, and what passes through each of them?

2. What synovial bursae can you name on the lower extremity? Where are they located?

3. Describe the structure of the femoral canal. Name the walls of the canal and of its rings (openings).

4. Name the walls of the adductor canal. Where is this canal located, and what does it contain?

5. Where is the cruropopliteal canal located? What is it bordered by and what does it contain?

6. Where are the superior and inferior musculoperoneal canals located? What lies in these canals?

VARIANTS AND ANOMALIES OF THE SKELETAL MUSCLES

Almost all muscles vary in shape, size, number of muscle fascicles and points of origin and insertion.

Muscles of the trunk

The trapezius muscle is sometimes divided by tendinous inscriptions into 2 or 3 parts. Its acromial or clavicular parts are sometimes absent. This muscle sometimes has two layers (superficial and deep).

The latissimus dorsi muscle may have additional serrations. Its tendon sometimes fuses with the tendon of the teres major muscle. Sometimes accessory fascicles of this muscle connect to the pectoralis major muscle.

The rhomboid major and minor muscles are often united with each other. One of these muscles may be divided into several separate fascicles, or may have a deep and superficial layers.

The seratus superior and inferior posterior muscles **may have a different** number of serrations (2 to 6 each). Sometimes these muscles are replaced by tendinous laminae.

The splenius capitis and cervicis muscles often fuse into one muscle.

In the erector spinae muscle some parts may be absent. The shape and size of the muscle may vary, as well as the number of fascicles and serrations.

Muscles of the occipital region. In rare cases one of these muscles may be absent. Sometimes these muscles may have additional fascicles, or may be split into two parts.

Muscles of the thorax

The pectoralis major and minor muscles vary in shape and size. The pectoralis major muscle sometimes splits into superficial and deep layers.

Serratus anterior muscle. The size and number of the serrations are variable.

External intercostal muscles. Sometimes one or several of these muscles may be replaced by tendinous fascicles.

Internal intercostal muscles. One or several of these muscles may be absent. Their fascicles sometime intertwine with fascicles of the neighboring muscles. The direction of the fascicles may vary.

The subcostales muscles may be absent.

The transversus thoracis muscle is often absent.

Muscles of abdomen

External oblique muscle of the abdomen. It may have different numbers of serrations. There may be additional fascicles directed toward the latissimus dorsi and inferior posterior serratus muscles.

Internal oblique muscle of the abdomen. In some cases it may be divided into a superficial and deep layers. Parts of this muscle may fuse with the transverse muscle of the abdomen.

The transverse abdominal muscle is sometimes absent. The number of its costal fascicles varies from 5 to 8.

Rectus abdominis muscle. The number and width of the tendinous intersections may vary (their quantity may be 1 to 6–7). Sometimes the

point of insertion of the muscle is shifted up to ribs 2–4. Occasionally, this muscle was found absent on one or, more rarely, both sides.

The pyramidalis muscle is often underdeveloped. In 25 percent of cases it is absent.

Muscles of facial expression

Occipitofrontalis muscle. Sometimes there is also a transverse occipital muscle, stretching from the occipital crest to the mastoid process of the temporal bone.

The temporoparietalis muscle is often absent.

The procerus muscle is sometimes absent.

Orbicularis oculi muscle. The absence of one of its parts is possible. There have been cases of enlargement of its orbital part.

The corrugator supercilii muscle is often absent or underdeveloped.

The nasalis muscle is in some rare cases absent.

The depressor septi nasi muscle is not consistently met.

The levator labii superioris muscle may be united with one of its neighboring muscles. It may also split into two or three muscles.

The orbicularis oris muscle is sometimes fused with adjacent muscles.

The zygomaticus major muscle is sometimes absent.

The zygomaticus minor muscle is inconstant. The point of origin of this muscle is sometimes shifted.

Risorius muscle. This muscle is often absent on one or both sides. Often it fuses with the minor zygomatic muscle.

Buccinator muscle. It may have accessory fascicles. The muscle may be split into two layers.

The depressor anguli oris muscle is sometimes absent.

The depressor labii inferioris muscle sometimes fuses with the adjacent muscles. It may also be absent.

The mentalis muscle is often absent, and sometimes is split into two parts.

Anterior, superior and posterior auricularis muscles. Sometimes one or all of these muscles are absent. There have been cases of fusion of these muscles into one.

Muscles of mastication

The temporal muscle sometimes gives off fascicles towards the other masticatory muscles

The masseter muscle sometimes has additional fascicles.

The **medial pterygoid muscles** may have additional fascicles.

The **lateral pterygoid muscle** may have a common origin with the medial pterygoid muscle. Sometimes one of its head is absent. The superior head may be fused with the temporal muscle.

Muscles of the neck

Platysma muscle. There had been cases when this muscle is partially or completely absent. It may have additional fascicles.

Sternocleidomastoid muscle. The number of its heads varies between 2 and 4. The muscle may be partially or completely absent. Occasionally, there is an accessory cleidomastoid muscle, which is inserted into the superior nuchal line.

The digastric muscle may have accessory fascicles, which connect its venters with neighboring muscles. Sometimes one of its venters is absent.

The stylohyoid muscle may be completely or partially split, or may have accessory fascicles.

Geniohyoid muscle. There have been cases of doubling of this muscle. Sometimes it is absent. It may also have accessory fascicles connecting it to neighboring muscles.

Sternohyoid muscle. This muscle has also been described to double. It may have accessory fascicles, and is sometimes absent. It may be split into a cleidohyoid and sternohyoid muscles.

Sternothyroid muscle. The point of origin of this muscle may vary (ribs 1 and 2).

The omohyoid muscle may lack the intermediate tendon. The number of its venters may increase to 3–5.

The thyrohyoid muscle is occasionally absent. It may be split into two parts, which have separate origins.

The anterior scalene muscle is, in some cases, absent, split into two parts, or united with the middle scalene muscle.

The middle scalene muscle is sometimes absent. It may be split, or its dorsal part may develop as a separate lateral scalene muscle.

The posterior scalene muscle may be absent. Its point of insertion may vary between ribs 3–5. It has been described in some cases to unite with the middle scalene muscle.

The longus colli muscle is sometimes absent. It may completely or partially fuse with the long muscle of the head.

The longus colli muscle is occasionally united with the long muscle of neck. It may be absent of split longitudinally into two parts.

The **rectus capitis anterior** and **rectus capitis lateralis** may be absent on one or both sides (in rare cases).

Muscles of the upper extremity

The deltoid muscle. Sometimes a part of this muscle is absent or underdeveloped. Its clavicular part may be a separate muscle. Fusion with the adjacent muscles is also possible.

The supraspinatus muscle is sometimes absent or underdeveloped.

The infraspinatus muscle may vary in size.

The teres minor muscle is sometimes absent. There have been cases of its fusion with the infraspinous muscle, and of separation of an inferior fascicle, which is inserted into the greater tubercle of the humerus.

The teres major muscle is occasionally absent. It may fuse with the tendon of the latissimus dorsi muscle or the tendon of the long head of the triceps.

The subscapularis muscle may split into several fascicles, which have different places of insertion (capsule of the shoulder joint, coracoid process, etc.).

The coracobrachialis muscle is sometimes absent. It may be split, or may have 2–3 accessory fascicles.

The biceps brachii muscle. One of the heads of this muscle may be absent. In very rare cases the whole muscle may be absent. The number of heads may increase to 3–5.

The brachialis muscle sometimes has two heads of origin, attached on either side of the deltoid tuberosity. This muscle sometimes unites with adjacent muscles.

The triceps brachii muscle rarely develops with anomalies. It has been recorded to divide into two parts. It may fuse with the infraspinous, the teres major or the anconeus muscle.

The anconeus muscle is sometimes absent.

The brachioradialis muscle sometimes originates from the deltoid tuberosity. It may be split along its whole length.

The pronator teres muscle is occasionally absent. The number of its heads may increase up to 3–4.

The flexor carpi radialis muscle may unite with the adjacent muscles, or may be divided longitudinally into two parts.

The palmaris longus muscle is absent in 25 percent of cases. It is sometimes split into two muscles. The relationship between the lengths of its venter and tendon may vary, as well as the points of insertion and origin, and the thickness of the muscle.

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The flexor carpi ulnaris may lack its ulnar part. It may unite with neighboring muscles (the palmaris longus muscle, etc.).

The flexor digitorum superficialis may lack its radial head or a tendon of one of the digits. Sometimes its tendons are inserted into the radial edge of the middle phalanx.

The flexor digitorum profundus may be missing a tendon of one of the digits. It may fuse with adjacent muscles.

The flexor pollicis longus is occasionally absent. It may have an additional fascicle, which stretches from the coronoid process of ulna.

The extensor carpi radialis longus may have up to 3–5 heads. Sometimes it is absent or is united with the adjacent muscles.

The extensor carpi radialis brevis may be fused with the extensor carpi radialis longus. This muscle is sometimes doubles and occasionally absent. It sometimes is inserted into the IV metacarpal bone.

The extensor digitorum may be divided into several separate muscles. There have been cases with an additional tendon stretching to the first digit, and lack of a tendon of the fifth digit.

The extensor digiti minimi is occasionally absent.

The extensor carpi ulnaris is sometimes doubled or fused with the neighboring muscles. It may have an additional tendon, which attaches to the capsule of the V metacarpophalangeal joint.

The supinator muscle sometimes divided into superficial and deep layers. On rare occasions this muscle is replaced by fibrous fascicles.

The abductor pollicis longus often unites with the short extensor of thumb. Sometimes it is partially of completely split. It may have an additional tendon, which stretches to the first metacarpal bone.

The extensor pollicis brevis may be partially or totally split. Part of its tendon fascicles may attach to the distal phalanx of thumb.

The extensor pollicis longus is occasionally absent. This muscle may be doubled, and may have an additional tendon, stretching towards the phalanges of the second digit. Its venter may fuse with the extensor muscle of index finger, or with the short extensor or long abductor muscle of thumb.

The extensor indicis is sometimes doubled. It may have an additional tendon, directed to the first finger. Sometimes this muscle is united with neighboring muscles.

The abductor pollicis brevis may fuse with adjacent muscles.

The flexor pollicis brevis may be underdeveloped, or may lack one of its head. Its deep head sometimes fuses with the opposer muscle of thumb.

The **opponens pollicis** may be united with adjacent muscles. Sometimes this muscle is absent.

In **the adductor pollicis** the transverse head sometimes develops as a separate muscle. There may also be additional fascicles, which are inserted into the II–III metacarpal bones.

The **palmaris brevis** muscle may originate from the triquetral or pisiform bones. This muscle may be absent.

The **abductor digiti minimi muscle** is occasionally absent. It may be doubled, or it can have additional heads of origin on the neighboring muscles.

The **flexor digiti minimi brevis** is occasionally absent. It may fuse with neighboring muscles, or may have an additional tendon.

The **lumbrical and interosseeous muscles.** One or several of these muscles may be doubled, or may be absent.

Muscles of the lower extremities

The **iliopsoas muscle.** The level of fusion between the iliac and major psoas muscles is variable.

The **psoas minor muscle** is inconstant. Sometimes this muscle is doubled.

The **piriformis muscle** may be absent, or may be divided into 2–3 parts.

The **gluteus maximus muscle** may be united with the gluteus medius or with the tensor muscle of fascia lata.

The **gluteus medius and minimus muscles** may be united with the piriform muscle or the tensor muscle of fascia lata. There is sometimes additional (fourth) gluteal muscle, which is inserted into the capsule of the coxal joint.

The **tensor of fascia lata muscle** may be absent or, occasionally, doubled.

Superior and inferior gemellus muscles. One or both of these muscles may be absent.

The **quadriceps femoris muscle** may have up to 5–6 heads of origin, or may lack one of its heads.

The **biceps femoris muscle** may have up to 3–4 heads. In some cases its short head may be missing.

The **semimembranosus muscle** is occasionally absent. Sometimes it has accessory fascicles, which form a tensor muscle of the crural fascia.

The **semitendinosus muscle** is occasionally absent, or may be doubled.

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The gracilis muscle is sometimes absent.

The pectineus muscle may be absent. It may insert on the greater trochanter of the femur.

Thet adductor brevis muscle may be absent, or may be divided into two venters by an intermediate tendon.

The adductor magnus muscle sometimes fuses with the adductor longus and brevis muscles, the lumbar quadrate muscle, or the semimembranosus muscle.

The triceps surae muscle may lack one of its heads, or may have additional heads, which originate from the popliteal surface of femur.

The popliteus muscle is sometimes absent.

The flexor digitorum longus may also occasionally be absent.

The tibialis anterior muscle may be doubles or may be absent. It may be inserted into the II–IV metatarsal bones.

The extensor hallucis longus muscle may be absent (very rare).

The peorneus longus muscle is sometimes absent. This muscle may be inserted into the on bases of the III–V metatarsal bones.

The peroneus brevis muscle may have an accessory fascicle, which is inserted into the dorsal surface of the fifth toe.

The extensor digitorum brevis muscle may be absent.

The extensor hallucis brevis muscle is occasionally absent.

The adductor hallucis is often split into two parts, which have their own tendons. It may also have an additional tendon, which is inserted into the proximal phalanx of the second toe.

The flexor hallucis brevis muscle, as all the other plantar muscles of the foot, may be absent or may unite with adjacent muscles.

SPLANCHNOLOGY
(THE STUDY OF INTERNAL ORGANS)

Internal organs are situated in regions of the head and neck, and in the thoracic, abdominal and pelvic cavities. They take part in metabolic functions of the organism, providing it with nutrients and eliminating the byproducts of metabolism.

According to their development, topographic characteristics, anatomy and functions internal organs are grouped into several organ systems and apparatuses. These include the digestive and respiratory systems, and the urogenital apparatus, which consists of the urinary and reproductive systems. The organs of the digestive system are located in the regions of the head, neck, thorax, abdomen and pelvis. The respiratory organs are situated within the neck and thorax, and the urogenital organs lie in the abdominal and pelvic cavities. Situated inside the thorax, next to the respiratory and digestive organs, is the heart — a vital organ of the cardiovascular system. The abdominal cavity contains the spleen, which is an organ of the immune system. Special significance is given to endocrine glands, which are situated in different separate regions of the body.

Internal organs can be divided into parenchymal and hollow (tubular) organs. **Parenchymal organs** consist of parenchyma, which is specialized tissue that carries out the specific function of the organ. Parenchymal organs always have a stromal capsule, which gives off connective tissue intercalations, or trabeculae, into the parenchyma. The stroma contains blood and lymph vessels, and nerves. It provides support and performs a trophic function. This group of organs includes the pancreas, the liver, the kidneys, the lungs and some other organs.

Hollow organs have a lumen and are shaped like tubes of different diameters. Despite some differences in their shape, the walls of tubular organs are similar in structure, and are formed by the following layers. The mucosa is the innermost layer; over it lies the submucosa, the muscularis and, on the outside, adventitia or serosa (Fig. 116). The walls of some tubular organs (trachea, bronchi) also contain a cartilage skeleton.

The mucosa (túnica mucósa) is the internal layer of tubular organs of the digestive, respiratory and urogenital systems. It consists of the surface epithelium and the lamina propria of mucosa. The surface epithelium lines the inside of the mucosa. Depending on its functions, the epithelium can be stratified squamous (oral cavity, pharynx, esophagus, and portion of rectum), transitional (urinary tract), and simple columnar, or prismatic
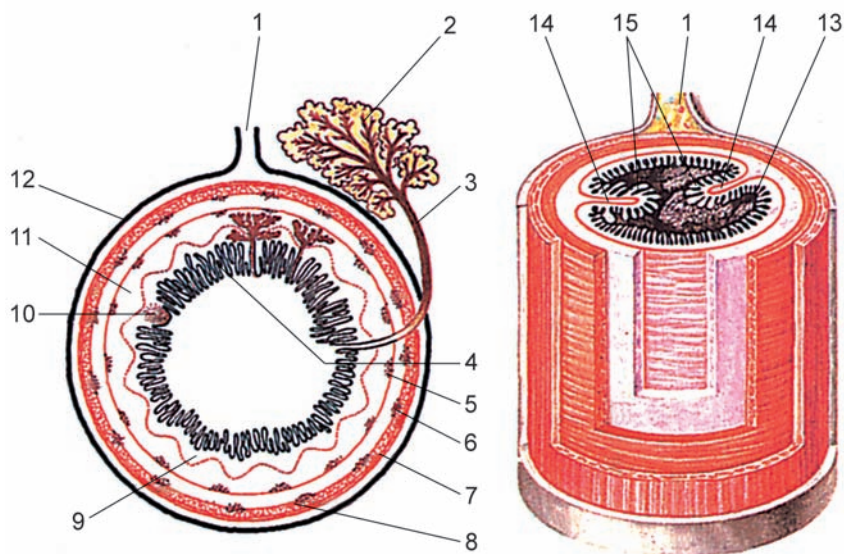
Fig. 116. Structure of digestive tube. Transverse (A) and longitudinal (B) sections.

1 — mesentery; 2 — compound digestive gland; 3 — gland duct; 4 — epithelium of mucous membrane; 5 — submucous nervous plexus (Meissner's); 6 — muscular-intestinal nervous plexus (Auerbah's); 7 — longitudinal layer of muscular coat; 8 — circular layer of muscular coat; 9 — lamina propria of mucous membrane; 10 — solitary lymphoid nodule; 11 — submucosa; 12 — serous coat; 13 — mucous membrane; 14 — folds of mucous membrane; 15 — interstinal villi.

(stomach, intestine, trachea). It can also be stratified ciliary (nasal cavity, larynx). Epithelial cells are connected with each other by specialized cell junctions (tight junctions, desmosomes, etc.), and thus form a continuous layer. The epithelium protects the underlying tissues. In some organs (intestine, kidneys, stomach, etc) it performs selective absorption of substances. Among epithelial cells there are unicellular glands called goblet cells, which secrete mucus. Mucus keeps the mucosa moist, protecting the epithelium. Beneath the epithelium is the basement membrane.

The basement membrane is approximately 1 mm thick. It consists of an amorphous substance and fibrous (reticular) structures. It contains glycoproteolipid complexes. Basement membranes are perforated by many round or oval fenestrae, 2.5–4.0 mm in diameter. These windows correspond to the places of contact between the basal membrane and the processes of adjoining fibroblasts. The basement membrane acts like an elastic support for the epithelial layer and serves as a barrier during filtration or diffusion. It also participates in nourishment or the epithelium, which

does not contain capillaries. One of the properties of the epithelium is polarity, which means that the basal and apical parts of the layer and of individual cells have a different structure. The epithelium is highly capable of regeneration.

Situated to the outside of the basement membrane is the lamina propria. It consists of loose fibrous connective tissue, which contains blood and lymph vessels, nerve fibers, lymphoid cells (lymphocytes, plasmocytes) and lymph nodules, and simple multicellular glands. The lamina propria supports the surface epithelium, provides it with nutrients and takes part in absorption of liquid and products of digestion (small intestine)

At the border between the mucosa and submucosa lies the muscular layer of the mucosa, formed by a thin layer of smooth muscle cells (1–3 myocytes thick). Some organs (tongue, gums) do not have this layer. During contraction of the muscular layer (l a m i n a   m u s c u l a r i s   m u - c o s a e) the mucosa forms folds.

There are two possible types of structure of the muscular lamina of mucosa. In organs which have simple epithelium, or the main function of which is absorption (stomach, small and large intestines), the myocytes of the lamina muscularis mucosae intertwine with each other, forming a network structure. In the organs, the main function of which is secretion, the smooth muscle cells have a more disorderly orientation.

The submucosa (téla submucósa) is situated on the outside of the mucosa. It consists of loose connective tissue, which is rich in elastic fibers. The submucosa contains a large number of blood and lymph vessels, which form vascular plexuses. Numerous nerve fibers form the submucosal (Meissner's) plexus. Due to the elasticity of the submucosa, it can contribute to formation of folds of the mucosal layer. In organs, where the submucosa is thin, folds of the mucosa are very small or are not formed at all.

Like the mucosa, the submucosa contains different simple branched glands, which secrete mucus and some bioactive substances (digestive enzymes). Some glands (for example, large salivary glands) are situated near a hollow organ, and communicate with it by an excretory duct, which opens on the surface epithelium.

Glands may have different shapes. Multicellular simple glands have an unbranched excretory duct. Compound glands have a more complicated system of branched tubes and alveoli, which open into one common duct. The parenchyma of a gland consists of epithelial tissue, which forms its secretory units and the duct system. Each secretory unit consists of approximately 10–20 epithelial cells, situated on a basement membrane. Outside the basement membrane there are myoepitheliocytes (basket cells),

which surround the secretory units with long cytoplasmic processes. Contraction of these processes, which contain contractile filament, promotes secretion to exit from the secretory cells into the lumen of the gland. Some glands (in walls of the esophagus, larynx and other organs) contain separate endocrine cells. The secretion of these cells (bioactive proteins, etc.) does not proceed into the excretory duct, but is absorbed by nearby blood and lymph capillaries.

The lumina of the secretory units form the initial parts of the gland ducts. The walls of these ducts are lined with epitheliocytes. In the beginning parts of the ducts of the epithelial cells also produce secretion. Small ducts join with each other, forming a common (main) excretory duct. This duct extends to the surface epithelium of a tubular organ. In some places it may have ampullar amplifications, which can serve as reservoirs for accumulation of secretion.

The connective tissue component of the gland (stroma) consists of a capsule and connective tissue septa, which divide the glandular parenchyma into sections. The stroma provides protection and support; it contains vessels and nerves, fibroblasts, mast cells and lymphoid elements. Large sections of glands are called lobes, and smaller sections are called lobules. The stromal trabeculae between lobes are called interlobar, while the trabeculae between lobules are called interlobular.

The muscularis externa (túnica musculáris) of tubular organs is made up of smooth muscle cells. Within the muscularis the myocytes form two layers. The internal layer is circular muscle, and the external layer is longitudinal muscle. Between the two layers there is a thin intermuscular connective tissue septa, which contains blood and lymph vessels, and a large number of nervous fibers, which form the myenteric plexus.

The muscularis layer of tubular organs carries out important functions. In the organs of the digestive tract it provides muscle tone and performs rhythmic contractions (peristalsis), by which the content of these organs is mixed and moved from the oral cavity towards the anal opening. In the respiratory organs the muscularis regulates the width of the lumina of bronchi. In the urogenital apparatus it regulates the lumina of the ducts of the urinary and reproductive systems.

The muscularis of the beginning and end sections of the digestive tract (mouth, pharynx, upper part of the esophagus, external sphincter of the rectus) and some parts of the respiratory pathways (larynx) contains striated muscle tissue, which we can contract voluntarily. In other tubular organs the muscular layer consists of smooth muscles.

In some places of the digestive tract the circular muscle layer of the muscularis forms thickenings called sphincters, which can narrow the lu-

men of the tubular organ. An example of this is the pyloric sphincter, situated at the border between the stomach and duodenum. By closing the lumen in this place it detains food inside the stomach for a certain period of digestion. The exit from the bladder has the internal smooth muscle sphincter, and the end section of the rectum has the internal anal sphincter.

The external layer of tubular organs (**adventítia**) is formed by loose fibrous connective tissue, which contains blood and lymph vessels and nerves. The adventitia not only covers and protects internal organs, but also attaches them to the walls of body cavities and to neighboring organs. Organs, which are situated in the abdominal cavity are covered on the outside by the serosa. The s e r o s a (peritoneum) lines the abdominal part of the esophagus, the stomach, the mesenteric part of the small intestie and parts of the large intestine. The serosa layer of the lungs is called pleura. The serosa is formed by a thin lamina of dense connective tissue (with elastic and collagen fibers), which is covered on the outside by simple squamous epithelium called mesothelium. Like adventitia, it contains blood and lymph vessels, and nerve fibers. The serosa also contains a large number of sensitive nerve endings.

TOPOGRAPHIC ORIENTATION POINTS OF INTERNAL ORGANS

Inside the body cavities the internal organs have a specific arrangement relative to each other, bones of the skeleton, muscles, nerves and vessels. In describing the location of organs several special anatomical concepts are used. The term «s k e l e t o t o p y» is used to define the position of an organ relative to the bones of the skeleton. The term «h o l o t o - p y» is used to determine the region of the body where the organ is located. The concept of «s y n t o p y» defines the position of organs relative to each other.

For more exact location of organs in the abdominal cavity and for defining their projection onto the surface, the abdomen is divided into several provisory regions. Two horizontal lines divide the anterior abdominal wall into tree stories. The intercostal line is drawn between the cartilages of the tenth ribs. The superior anterior spines of iliac bones are connected by the interspinous line. Above the intercostal line is the upper abdomen, or the e p i g a s t r i c r e g i o n. Between the intercostal and interspinous lines is the middle abdomen, or the m e s o g a s t r i c r e g i o n. The lower abdomen is called the h y p o g a s t r i c r e g i o n (hypogastrium).

Each of the three stories is divided into three sections by two vertical lines, drawn along the lateral edges of the rectus abdominis muscles (between the costal arch and the pubis). Thus, the epigastric region is divided

into the e p i g a s t r i u m and the r i g h t and l e f t h y p o c h o n d r i a c (subcostal) r e g i o n s. The mesogastric region is divided into the r i g h t and l e f t l u m b a r r e g i o n s and the umbilical region between them. The hypogastric region is divided into the r i g h t and l e f t i l i a c (i n - g u i n a l) r e g i o n s and the p u b i c (hypogastric) r e g i o n.

Questions for revision and examination

1. What two groups are internal organs divided into? Describe the structure of these organs.
2. What layers do walls of hollow organs consist of?
3. Describe the structure of the mucosa of internal organs.
4. What forms of glands can be found in internal organs? What structures promote discharge of secretion from glands?
5. Describe the structure of the muscularis layer of tubular organs.
6. What regions are defined on the front wall of the abdomen? What lines mark the borders between these regions?

THE DIGESTIVE SYSTEM

The **digestive system (systéma digestórium)** includes the oral cavi-ty, the pharynx, the esophagus, the stomach and the small and large intes-tines (Fig. 117). The digestive system also includes the major salivary glands, the liver and the pancreas. Functions of the digestive system are mechanical and chemical break down of food, absorption of products of digestions, and elimination of unabsorbed or undigested substances.

The beginning of digestion takes place in the mouth, or oral cavity. In the mouth food is broken down by teeth, or chewed, and mixed together with saliva. Saliva is secreted by salivary glands, the excretory ducts of which open through the mucosa of the mouth. From the oral cavity food moves into the pharynx, then the oesophagus, and into the stomach. Food masses are retained in the stomach for a certain period, during which they become liquefied by gastric juices, are digested and begin to be absorbed. Partially digested food masses move into the small intestine, where they are mixed with bile from the liver and pancreatic juices. In the small intes-tine, which consists of the duodenum, jejunum and ileum, digestion by digestive enzymes (chemical break down) is completed, and nutrients (ami-no acids, simple sugars, emulsified fats) are absorbed into blood and lymph capillaries of the intestinal wall. The unabsorbed and undigested food mass passes into the large intestine, the functions of which are absorption of water, salts and vitamins, and formation of feces. Feces continue to move through the large intestine, towards the anal orifice. The large intestine is divided into the cecum, the ascending, transverse and descending colons, the sigmoid colon, and the rectum.

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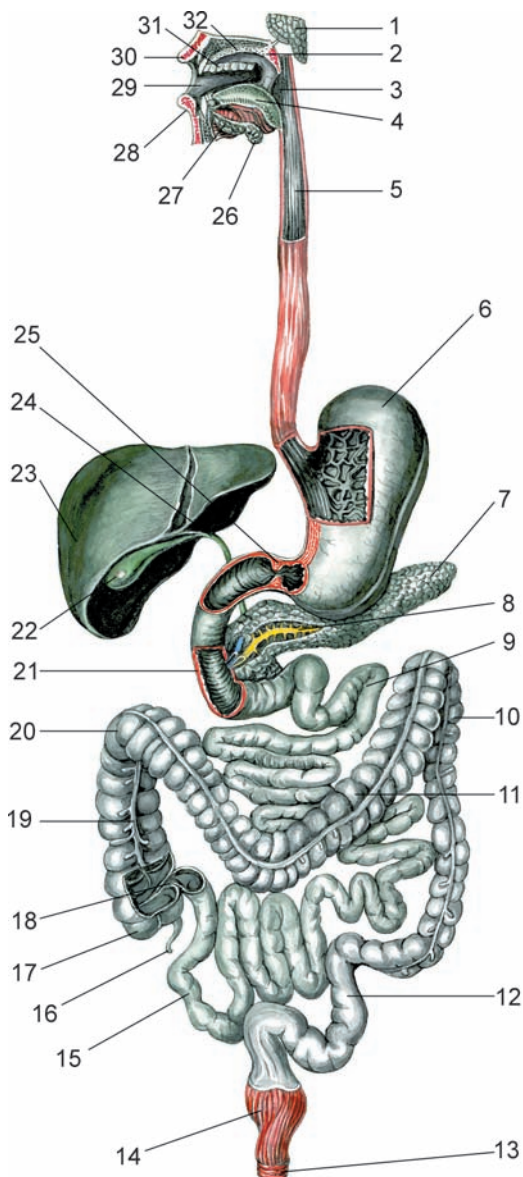
Fig. 117. Structure of digestive system.

1 — parotid (salivary) gland; 2 — soft palate; 3 — pharynx; 4 — tongue; 5 — oesophagus; 6 — stomach; 7 — pancreas; 8 — pancreatic duct; 9 — jejunum; 10 — descending colon; 11 — transverse colon; 12 — sigmoid colon; 13 — external anal sphincter; 14 — rectum; 15 — ileum; 16 — vermiform process; 17 — caecum; 18 — ileocaecal valve; 19 — ascending colon; 20 — right colic flexure; 21 — duodenum; 22 — gallbladder; 23 — liver; 24 — bile duct; 25 — pyloric sphincter; 26 — submandibular (salivary) gland; 27 — sublingual (salivary) gland; 28 — lower lip; 29 — oral cavity; 30 — upper lip; 31 — teeth; 32 — hard palate.

THE ORAL CAVITY

The oral cavity (cávum óris) is situated in the lower region of the face, and is the beginning of the digestive system. On the bottom it is limited by the mylohyoid muscles, which form the lower wall, or diaphragm, of the oral cavity. Its upper wall is formed by the hard and soft palates. At the sides the mouth is limited by the cheeks, and in the front— by the lips. In the back of the mouth is a large opening called the fauces, which communicates it with the pharynx. The oral cavity is divided into two sections. The smaller front section, or the v e s t i b u l e (vestíbulum óris), is situated between the lips and cheeks, and the teeth. Behind the teeth is the o r a l   c a v i t y   p r o p e r (cávitas óris própria).

The g i n g i v a e, or gums, are formed by the alveolar processes of the maxillae and the alveolar part of the mandible, which are covered by mucosa. The vestibule and the oral cavity proper communicated by a narrow fissure between the upper and lower teeth. The o r a l   f i s s u r e (inlet into the vestibule) is located between the upper and lower lips, which are connected at the sides by labial c o m m i s s u r e (commissúra labiórum). The l i p s are formed by the orbicularis oris. The c h e e k s (búccae) are formed by the buccinator muscles. Between these muscles and the skin lies an accumulation, or lump, of adipose tissue (Bishe's lump), which is usually best developed in infants. During this age the lump thickens the walls of the oral cavity, lowering the influence of atmospheric pressure, and, thus, easing the act of sucking.

Palate

The palate is divided into the hard and soft sections. The hard palate is formed by the palatine processes of the maxillae and the horizontal laminae of the palatine bones. The s o f t   p a l a t e is attached to the posterior edge of the hard palate. It is formed by a connective tissue lamina, which is covered by mucosa. The anterior end of the soft palate lies horizontally, while its posterior end hangs down, and is called the p a l a t i n e v e l u m. From the middle of the posterior edge hangs a small rounded process called the uvula. Beginning at each lateral edge of the soft palate are two mucosal folds (arches). The p a l a t o g l o s s a l   a r c h extends to lateral edge of the root of the tongue. The p a l a t o p h a r y n g e a l   a r c h extends to the lateral wall of the pharynx. Between these arches, within the t o n s i l l a r   f o s s a lies the palatine tonsil, which is an organ of the immune system.

Within the structure of the soft palate there are several paired striated muscles (Fig. 118).

The tensor veli palatini muscle (m. ténsor véli palátini), originates from the cartilage part of the auditory tube and the spine of the sphenoid bone. It stretches downward, curves about the hook of the pterygoid process, turns medial and is inserted into the palatine aponeurosis. This muscle stretches the soft palate and widens the lumen of the auditory tube. The levator veli palatini muscle (m. levátor véli palátini) originates from the front inferior surface of the pyramid of the temporal bone and on the cartilage part of the auditory tube. It passes medial of the previous muscle is inserted into into the palatine aponeurosis. During contraction it raises the soft palate. The musculus uvulae (m. uvúlae) originates on the posterior nasal spine and inserts into the mucosa of the uvula. During contraction it raises and shortens the uvula. The palatoglossus muscle

Fig. 118. Muscles of soft palate.

1 — tensor veli palatini; 2 — levator veli palatini; 3 — hamulus of pterygoid process; 4 — palatoglossus; 5 — musculus uvulae; 6 — palatopharyngeus.

(m. palatoglóssus) originates within the lateral part of the root of the tongue, stretches upward inside the homonymous arch, and inserts into the palatine aponeurosis. This muscle lowers the palatine velum, decreasing the size of the fauces. The palatopharyngeus muscle (m. palatopharýngeus) originates from the posterior wall of the pharynx and the posterior edge of the cricoid cartilage. It inserts into the palatine aponeurosis. During contraction it lowers the palatine velum, narrowing the fauces.

The mucosa of the mouth is lined by striated squamous epithelium (its thickness ranging between 180–600 mm). In some places this mucosa lacks the muscular lamina. In the regions of the gums, tongue and hard palate there is no submucosal layer. On the hard palate the mucosa may form 1–6 transverse folds. There are small folds in the region of the tonsils. The mucosa of the mouth contains a large number of glands.

Teeth

Teeth are vital anatomical formations situated in the dental alveoli of the jaws. They are grouped according to their structural characteristics, location and function. Teeth are divided into i n c i s o r s (d é n t e s i n - c i s í v i), c a n i n e s (d é n t e s c a n í n i), p r e m o l a r s (d é n t e s p r e - m o l á r e s) (Fig. 119), and m o l a r s (d é n t e s m o l á r e s). Incisors are used mainly for seizing and biting food; canines are used for tearing; molars and premolars are for grinding food. The general structure of different types of teeth is similar. A tooth consists of the crown, the neck and the root (Fig. 120). The c r o w n, which is situated above the gingiva, is the largest part of the tooth. On it there are several surfaces. Its l i n g u a l s u r f a c e faces the tongue; the v e s t i b u l a r s u r f a c e faces the vestibule; and the c o n t a c t s u r f a c e s face the adjacent teeth. The o c c l u s - a l s u r f a c e s of analogous teeth of the maxilla and mandible are turned towards each other. On the inside of the tooth there is a c a v i t y, occupied by the p u l p. The r o o t of the tooth articulates with the dental alveolus by a gomphosis, which is a type of synarthrosis. Each tooth has 1–3 roots. The root ends with an apex, which is perforated by an opening. Between the crown and the root is the n e c k of the tooth, which is surrounded by mucosa of the gingiva. The crown part contains the p u l p c a v i t y, which continues into the r o o t c a n a l. Through the a p i c a l f o r a m e n and the root canal an artery and a nerve enter the pulp cavity, and a vein leaves it. The pulp is formed by loose fibrous connective tissue, which contains fibroblasts and other cells. The bulk of the tooth is formed by the dentine. In the region of the crown it is covered by the enamel, while its neck and root are surrounded by cellular cement. The enamel is an extremely durable substance. It is formed by enamel prisms 3–5 mm thick, which are separated from each other by an interprismatic component. This component has less electron density than the enamel prisms. On the surface the e n a m e l is covered by a thin cuticle. The composition of the enamel is mostly inorganic salts (96–97 percent), which include primarily calcium carbonate and calcium phosphate. The enamel also contains almost 4 percent calcium fluoride. The d e n t i n e contains approximately 28 percent organic substances (primarily collagen) and 72 percent inorganic material. The inorganic material consists mostly of calcium phosphate, magnesium phosphate and calcium fluoride. The structure of the cement resembles bone tissue. It is formed by calcified laminae, between which there are lacunae, containing multipro- cessed cementocytes. The c e m e n t also contains collagen fibers, which tightly accrete the root with the periodontal ligament. Around the neck of the tooth the cement is thin and does not contain cells (acellular cement).
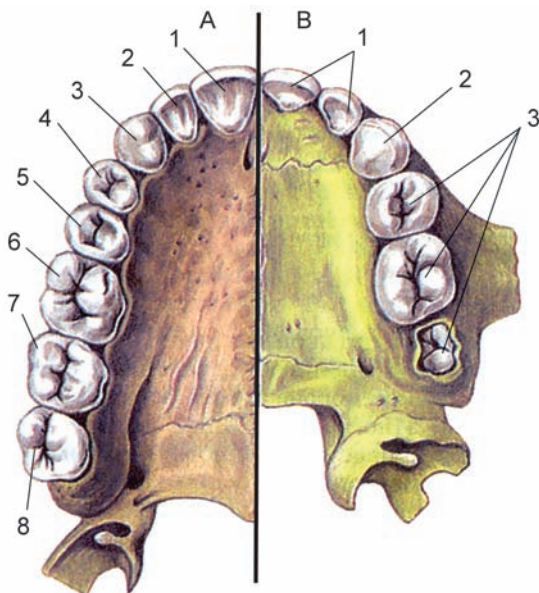
Fig. 119. Teeth of maxilla.

A — permanent teeth; 1 — medial incisor; 2 — lateral incisor; 3 — canine; 4 — first premolar tooth; 5 — second premolar tooth; 6 — first molar tooth; 7 — second molar tooth; 8 — third molar tooth (Wisdom tooth). B — deciduous teeth of a 4 — year child: 1 — incisors; 2 — canine; 3 — molar teeth.

The composition of cement is 29.6 percent organic substances and 70.4 percent inorganic matter (primarily calcium phosphate and bicarbonate).

Teeth can also be classified as milk, or deciduous, and permanent. D e c i d u o u s   t e e t h develop in children between the 5–7 months of age. Afterwards these teeth are shed and replaced by permanent teeth. Compared to permanent teeth, milk teeth have wider and shorter roots. The half of each jaw has 2 milk incisors, 1 canine and 2 milk canines (20 milk teeth altogether). There are no deciduous premolars.

Shortly before eruption of a permanent tooth the deciduous tooth falls out. P e r m a n e n t   t e e t h begin to appear during the age of 6–7, and continue to erupt until ages 13–15. The first permanent teeth to erupt are the inferior molars; then the medial incisors and first superior molars. After them come the lateral incisors, followed by the first premolars, the canines, the second premolars, and then the second molars. The last to erupt (between ages 12–26) are the so-called wisdom teeth (third molars). The half of each jaw has 2 incisors, 1 canine, 2 premolars and 3 molars (Fig. 187 and 188). Altogether, there are 32 permanent teeth.

Different types of teeth are distinguished by their shape (Fig. 121). Incisors have a wide flattened crown with a sharp edge. The crowns of the

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upper teeth are wider then those of the lower. They have one conical root, which in lower incisors is somewhat pressed at the sides. Depending on their position relative to the median plane the incisors are called medial and lateral.

The canine teeth have a conical sharpened crown and a single root, which is pressed from the sides. The roots of lower canines are shorter then of the upper. Sometimes their root may be doubled.

The premolars are situated to the back of the canines. The chewing surface of their crown is round or oval, and has two masticatory tubercles. The height of their crown is significantly less then of the canines. Premolars have a single conical root. In superior premolars it is sometimes bifurcated.

The molar teeth are situated behind the premolars. Their crown has a cuboid shape. On the chewing surface there are 3–5 tubercles. The upper molars have 3 roots in the upper jaw, and 2 roots the lower ones have. They decrease in size from front to back, so that the wisdom teeth are the smallest.
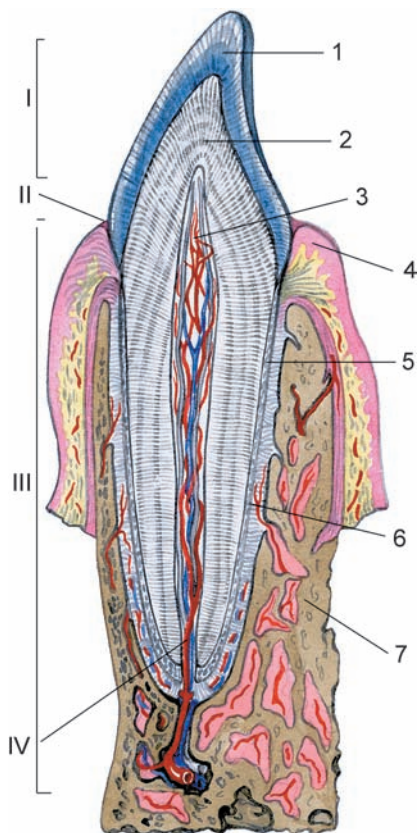
Fig. 120. Structure of a tooth.

1 — enamelum; 2 — dentinum; 3 — tooth pulp; 4 — gingiva; 5 — cementum; 6 — periodontium; 7 — bone. I — crown; II — dental neck; III — dental root; IV — tooth canal.

Tongue

The tongue (língua) is a muscular organ, which participates in the mechanical processing of food, in the act of swallowing, taste perception and formation of speech. It is situated in the oral cavity and is elongated flattened in shape (Fig. 122). In the front it has a narrow a p e x (tip). The apex continues into a thick broad b o d y, behind which lies the r o o t of the tongue. The upper convex surface of the tongue is called the d o r s u m. The lower surface is present only in its front section. The m a r g i n s of the tongue are somewhat rounded. On the upper surface, along the median

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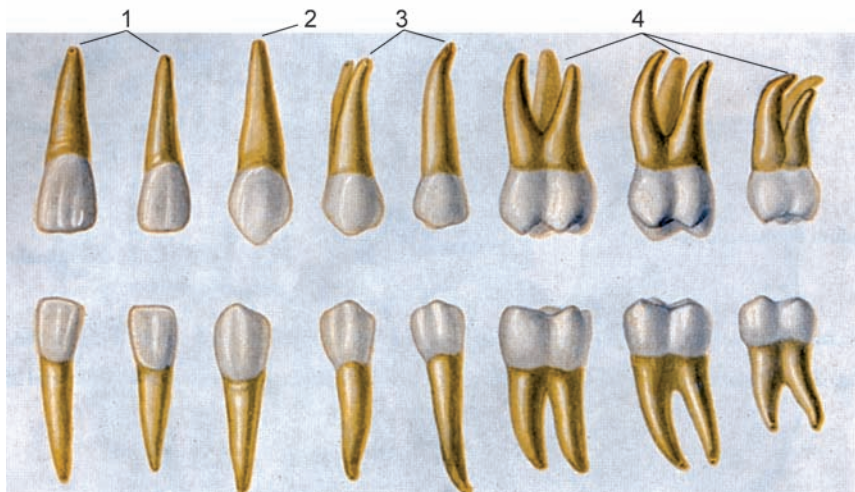
Fig. 121. Permanent teeth, right side; lingual facet.
1 — incisors; 2 — canines; 3 — premolar teeth; 4 — molar teeth.

line, passes the m e d i a n g r o o v e o f t h e t o n g u e. Beneath this groove is a fibrous plate, which divides the tongue into the right and left halves. In the back the median groove ends as the f o r a m e n c a e c u m. To the right and left of this foramen, towards the front, extends the V-shaped t e r m i n a l s u l c u s. This sulcus separates the body of the tongue from its root. In the region of the root lies the l i n g u a l t o n s i l, which is an important immune organ.

On the outside the muscles of the tongue are covered by mucosa. The surface of the dorsum has a velvety texture, because it is covered by papillae. Each papilla is a protrusion of the lamina propria of mucosa, which is covered by striated squamous epithelium. The connective tissue part of the papillae contains a large number of blood capillaries, while the epithelium contains gustatory nerve endings.

F i l i f o r m and c o n i c a l p a p i l l a e (p a p í l l a e f i l i f ó r m e s e t p a p í l l a e c o n i c a e) are the most numerous. They are spread diffusely over the entire dorsum region. They are approximately 0.3 mm in length. F u n g i f o r m p a p i l l a e (p a p í l l a e f u n g i f ó r m e s) are situated primarily on the apex and sides of the tongue. Their bases are narrower than the apexes. They are 0.7–1.8 mm long, and 0.4–1.0 mm in diameter. The epithelium of these papillae contains taste buds (3–4 on each papilla), which perceive taste. V a l l a t e p a p i l l a e (p a p í l l a e v a l l á t a e) are small papillae, embanked by a sort of torus (Fig.139). From 7 to 12 of these are situated along the border between the root and the body of the tongue, in

front of the terminal sulcus. Vallate papillae are 1–1.5 mm long and 1–3 mm in diameter. They have a narrow base and a broad, flattened upper part. They are surrounded by a circular groove (flute), which separates the papilla from the surrounding torus. The epithelium of the sides of the papilla and the torus contains numerous taste buds. F o l i a t e   p a p i l l a e (p a p í l l a e   f o l i á t a e) are situated on the side edges of the tongue in the form of elongated plates 2–5 mm long. These papillae also contain taste buds.

The mucosa of the tongue is not uniform in different regions. The region of the dorsum lacks the submucosa and is tightly accreted with the muscles of the tongue. Mucosa on the root of the tongue has numerous recesses and protrusions, beneath which lies the lingual tonsil. On the underside

Fig. 122. Tongue, laryngopharynx. Superior aspect.

1 — apex of tongue; 2 — body of tongue; 3 — margin of tongue; 4 — middle groove of tongue; 5 — foliate papillae; 6 — fungiform papillae; 7 — vallate papillae; 8 — terminal sulcus of tongue; 9 — foramen caecum of tongue; 10 — root of tongue; 11 — lingual tonsill; 12 — median glosso-epiglottic fold; 13 — epiglottis; 14 — piriform recess; 15 — aryepiglottic fold; 16 — rima vocalis; 17 — interarytenoideal notch.

of the tongue the mucosa is well developed, which promotes formation of folds. At the tip of the tongue there are two fringe folds. On the transition between the underside of the tongue and the mouth floor the mucosa forms a sagittal fold called t h e   l i n g u a l   f r e n u l u m. Situated at either side of the frenulum are two sublingual papillae. On each sublingual papilla are the excretory duct openings of the submandibular and the sublingual salivary glands. Behind each papilla is a sublingual fold, beneath which lies the homonymous salivary gland.

The paired striated muscles of the tongue are subdivided into proper muscles, and muscles which originate from the bones of the skeleton (skeletal muscles). The proper muscles originate and are inserted within the limits of the tongue.

Proper muscles of the tongue. The superior longitudinal muscle (m. longitudinális supérior) is situated along the sides of the median lingual groove, beneath the mucosa. It originates from the region of the root of the tongue and ends in its tip. During contraction this muscle shortens the tongue and raises its tip. The inferior longitudinal muscle (m. longitudinális inférior) lies in the lower part of the tongue. It originates from the root of the tongue and ends in the apex. During contraction it shortens the tongue and lowers its tip. The transverse muscle (m. transvérsus línguae) lies between the superior and inferior longitudinal muscles. It is formed by fascicles, which originate in the fibrous septa of the tongue and end in its sides. This muscle narrows the tongue, raising the dorsum. The vertical muscle (m. verticális línguae) is present primarily in its side regions. Its fascicles stretch between the mucosa of the dorsum of the tongue and its underside. By contracting it flattens the tongue.

Skeletal muscles of the tongue. The genioglossus muscle (m. genioglóssus) originates on the mental spine of the mandible, spreads out upward and to the back, and ends inside the tongue. During contraction it pulls the tongue downward and to the front. The hyoglossus (m. hyoglóssus) originates from the greater horn of the hyoid bone and ends in the lateral section of the tongue. This muscle shifts the tongue downward and to the back. The styloglossus (m. styloglóssus) originates from the styloid process, stretches forward, medially and downwards, and is inserted into the tongue from the side. During bilateral contractions it pulls the tongue up and to the back. During unilateral contraction it shifts the tongue to the side (table 16).

Table 16. Skeletal muscles of the tongue.

Muscle	Origin	Insertion	Action	Innervation
Genioglossus	Mental spine of mandible	Apex and base of the tongue	Draws the tongue forward and down	Superior laryngeal nerve
Hyoglossus	Body and greater horn of the hyoid bone	Lateral part of the tongue	Draws the tongue downward and to the back	Inferior laryngeal nerve
Styloglossus	Styloid process of temporal bone	Lateral inferior parts of the tongue	Draws the tongue upward and to the back	same as above

Motor innervation of the tongue — hypoglossal nerve; sensitive innervation — lingual nerve (anterior two thirds of the tongue) and glossopharyngeal nerve (posterior third); gustatory innervation — tympanic cord (anterior two thirds) and glossopharyngeal nerve (posterior third).

Blood supply: lingual artery;

Venous outflow: lingual vein.

Lymph outflow: mental, submandibular and deep cervical lymph nodes.

Salivary glands

Glands of the mouth include the minor and major salivary glands. The minor salivary glands are found in the mucosa and submucosa of the oral cavity. Their size varies between 1 and 5 mm. According to their topography glands can be called labial, buccal, molar (situated next to the molar teeth), palatine or lingual. The major salivary glands are situated outside the walls of the oral cavity, and are connected to it by excretory ducts. Independent of topography or size, all large salivary glands are similar in structure. They are compound alveolar or tubuloalveolar glands, derived from the ectoderm. These glands have a body (main section) and an excretory duct. The body consists of the parenchyma and the stroma of the gland. The beginning (secretory) sections are subdivided, according to the composition of their secretion, into the protein-producing (serous), mucus-producing (mucosal) and mixed types. According to a mechanism of secretion all salivary glands are of the merocrine type. The serous glands produce thin secretion, which is rich in enzymes. The mucosal glands produce a thicker, more viscous secretion, rich in mucin, which contains glycosaminoglycans.

The excretory ducts of the glands are subdivided into the intralobular and interlobular ducts and the common excretory duct. The intralobular ducts have two parts called the intercalary ducts (the beginning of the duct apparatus) and the striated ducts. The striated ducts continue into the interlobular ducts, which are connected to form the common duct. The intercalary ducts are usually lined by cuboidal and prismatic epithelium. The striated ducts are lined by columnar epitheliocytes, which are characterized by folds of the basal membrane. Between these folds there are a lot of mitochondria, which give these cells the appearance of striation. The interlobular ducts are lined with bistratified epithelium, which gradually passes into squamous. The common excretory duct is usually lined with stratified cuboidal epithelium, and in the region of it's opening — by striated squamous epithelium.

Excretory ducts of different salivary glands have certain individual characteristics. In the submandibular gland the intercalary ducts are shorter and less branched than in the parotid gland. In the sublingual gland the intercalary and striated ducts are almost undeveloped.

According to the type of secretion the lingual salivary glands are primarily serous. There are some mucosal glands on the root of the tongue and its sides. The glands of the anterior section of the tongue produce mixed secretion. The palatine glands are mucosal. The buccal, molar and labial glands are also mixed.

The salivary glands regularly secrete saliva into the oral cavity, thus carrying out an exocrine function. The composition of saliva is water (approximately 99 percent), mucus (mucin), enzymes (amylase, maltase), inorganic substances and immunoglobulins. Saliva moistens the food and the mucosa inside the oral cavity. Its enzymes break down polysaccharides into disaccharides and monosaccharides (glucose).

Major salivary glands (Fig. 123, 124). **The parotid gland (glándula parotídea)** is paired; it produces serous secretion. It is irregular in shape and is covered by a thin capsule. Its mass is 20–30 g. The gland is situated in front of and below the auricular concha, on the side surface of the ramus of mandible. At the top it adjoins to the zygomatic arch; at the bottom it extends to the angle of mandible; and in the back it reaches the mastoid process and the anterior edge of the sternocleidomastoid muscle. The deep part of the gland adjoins the styloid process and the stylohyoid, styloglossal and stylopharyngeal muscles. The gland is perforated by the external carotid artery, the retromandibular vein and the facial and auriculotemporal nerves. Inside the gland lie the parotid lymph nodes. The excretory duct of the parotid gland (p a r o t i d, or Stensen's d u c t) comes out from beneath its anterior edge, passes to the front 1–2 cm below the zygomatic arch, along the outer surface of the masseter muscle. It rounds the anterior edge of this muscle, perforates the buccinator muscle and opens into the vestibule of mouth at the level of the second upper molar.

S e n s i t i v e   i n n e r v a t i o n — parotid branches of the auriculotemporal nerve; s e c r e t o r y   (p a r a s y m p a t h e t i c)   i n n e r v a t i o n — fibers of the auriculotemporal nerve (from the auricular node); s y m p a t h e t i c — the external carotid plexus.

B l o o d   s u p p l y: parotid branches of the superficial temporal artery;

Ve n o u s   o u t f l o w: retromandibular vein.

L y m p h   o u t f l o w: superficial and deep parotid lymph nodes.
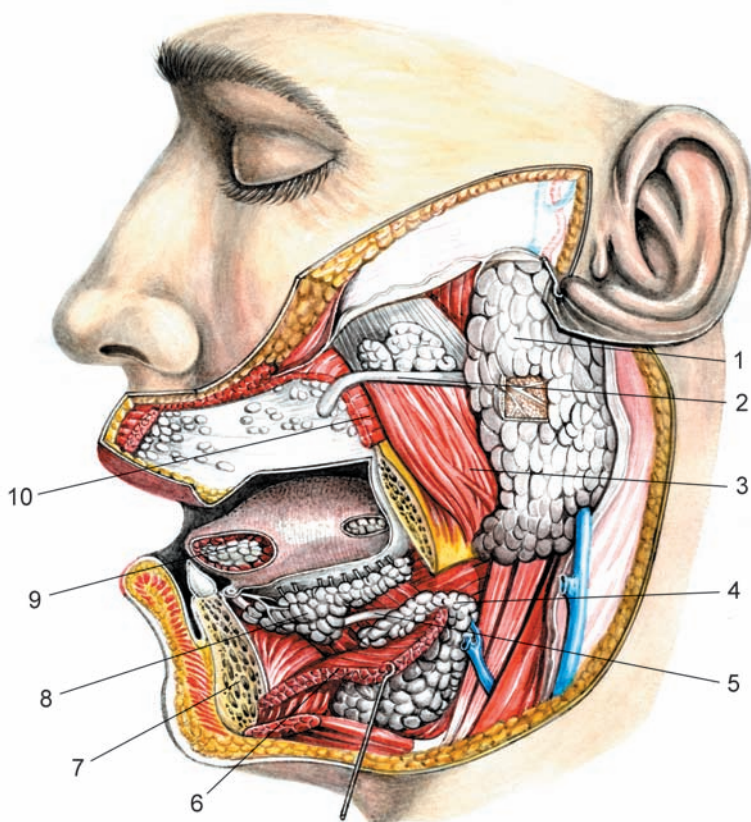
Fig. 123. Major salivary glands (left half of mandible is removed).

1 — parotid gland; 2 — parotid duct; 3 — masseter; 4 — submandibular gland; 5 — submandibular duct; 6 — mylohyoid; 7 — mandible; 8 — sublingual gland; 9 — tongue; 10 — buccinator.

The submandibular gland (glánudula submandibuláris) is paired, produces mixed secretion and has a well-developed capsule. It is situated in the region of the submandibular triangle of the neck. On the outside the gland is covered by the superficial lamina of the cervical fascia and the skin. The inner surface of the gland adjoins the hyoglossal and styloglossal muscles. At the top it reaches the inner surface of the body of the mandible. The anterior part of the gland protrudes to the back edge of the mylohyoid muscle. Its lateral surface adjoins the facial artery and vein, and the nearby lymph nodes. The s u b m a n d i b u l a r (Wharton's) duct passes forward, adjoining the sublingual gland. It opens on the sublingual papilla, next to the lingual frenulum.
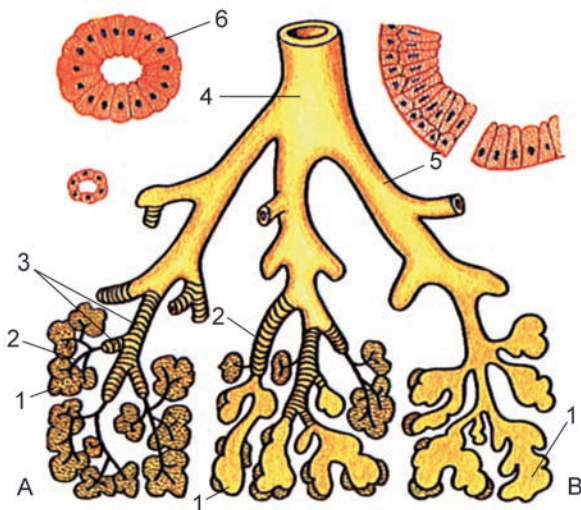
Fig. 124. Structure of major salivary glands (scheme).

A — serous secretory units. B — mucous secretory units. 1 — secretory units; 2 — intercalary duct; 3 — striated duct; 4 — gland duct; 5 — interlobular ducts; 6 — glanduloocytes.

S e c r e t o r y (p a r a s y m p a t h e t i c) i n n e r v a t i o n — fibers of the facial nerve (through the tympanic cord and submandibular node); s y m - p a t h e t i c — external carotid plexus.

B l o o d s u p p l y: glandular branches of the facial artery.

Ve n o u s o u t f l o w: submandibular vein.

L y m p h o u t f l o w: submandibular lymph nodes.

The sublingual gland (glándula sublinguális) is paired; produces primarily mucosal secretion. It is situated on the superior surface of the mylohyoid muscle, directly beneath the mucosa of the oral cavity floor. Its lateral surface adjoins the internal surface of the body of the mandible in the region of the sublingual fossa. Medially it adjoins the genioglossal, geniohyoid and hyoglossal muscles.

The m a j o r s u b l i n g u a l d u c t (main excretory duct) opens on the sublingual papilla. Several minor (additional) sublingual ducts open on the surface of the s u b l i n g u a l f o l d.

S e c r e t o r y (p a r a s y m p a t h e t i c) i n n e r v a t i o n — fibers of the facial nerve (through the tympanic cord and submandibular node); s y m - p a t h e t i c — external carotid plexus.

B l o o d s u p p l y: sublingual and mental arteries.

Ve n o u s o u t f l o w: sublingual vein.

L y m p h o u t f l o w: submandibular and mental lymph nodes.

1. What structures form the walls of the oral cavity?
2. Name the muscles of the soft palate and their points of origin and insertion.
3. Describe the structure of a tooth. What differences are there between different types of the teeth?
4. Name the periods of eruption of deciduous and permanent teeth.
5. What papillae are found on the surface of the tongue? Which of them contain taste buds?
6. Name the anatomical groups of muscles of the tongue. What is the function of each muscle?
7. Name different groups of small salivary glands.
8. Where in the oral cavity do the ducts of the large salivary glands open? How are these glands classified according to their structure and type of secretion?

PHARYNX

The pharynx is an unpaired organ, situated in the region of the head and neck (Fig.125, 126). It is part of both the digestive and the respiratory systems. It is shaped like an infundibular tube, which is fixed on the base of the skull. Its upper part (v a u l t o f p h a r y n x) attaches to the pharyngeal tubercle of the occipital bone, sides of pyramids of the temporal bones (in front of the external carotid opening), and to the medial laminae of the pterygoid processes. At the bottom it continues into the esophagus at the level of C4 vertebra. In an adult the pharynx is 12–15 cm long. Behind the pharynx lie the prevertebral muscles, the prevertebral lamina of the cervical fascia, and the cervical part of the spine. Between the pharynx and the fascia is the r e t r o p h a r y n g e a l s p a c e, filled with loose fibrous connective tissue. Within this space lie the retropharyngeal lymph nodes.

On both sides the pharynx is adjoined by the common and internal carotid arteries, the internal jugular vein, the vagus nerve, the greater horn of the hyoid bone and the thyroid cartilage of the larynx.

On the anterior wall of the pharynx are openings of the choanae. Below them is the fauces, and lower than that—the entrance into the larynx. The pharynx is divided into the n a s o p h a r y n x, situated behind the choanae; the o r o p h a r y n x, situated between the palatine velum and the entrance into the larynx; and the l a r y n g o p h a r y n x, situated between the entrance into the larynx and the transition into the esophagus. The nasopharynx is part of the respiratory system, while the oropharynx pertains to the digestive tract.

In the region of the vault of the pharynx, in the transitional region between its superior and posterior walls, there is an accumulation of lymphoid tissue (the p h a r y n g e a l t o n s i l). On the lateral walls, next to the back edge of the inferior nasal concha, is the p h a r y n g e a l o p e n - i n g o f t h e a u d i t o r y t u b e. The auditory (Eustachian) tube con-
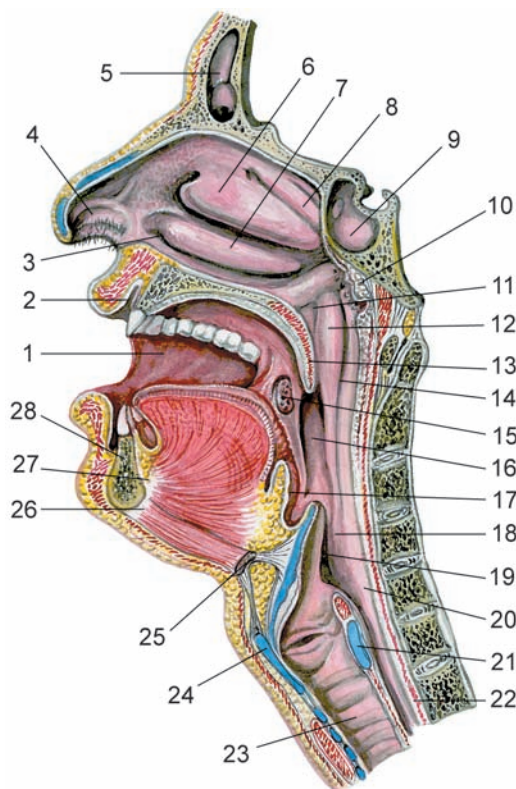
Fig. 125. Oral cavity and pharyngeal cavity (sagittal section of head).

1 — oral cavity proper; 2 — vestibulum oris; 3 — inferior nasal concha; 4 — nasal vestibulum; 5 — frontal sinus; 6-middle nasal concha; 7 — inferior nasal concha; 8 — superior nasal concha; 9 — sphenoidal sinus; 10 — pharyngeal tonsil; 11 — pharyngeal opening of auditory tube; 12 — torus tubarius; 13 — soft palate (velum palatinus); 14 — oropharynx; 15 — palatine tonsil; 16 — isthmus of fauces; 17 — root of tongue (lingual tonsil); 18 — epiglottis; 19 — aryepiglottic fold; 20 — laryngopharynx; 21 — cricoid cartilage; 22 — oesophagus; 23 — trachea; 24 — thyroid cartilage; 25 — hyoid bone; 26 — mylohyoid; 27 — genioglossus; 28 — mandible.

nects with the tympanic cavity, equalizing the pressure inside the middle ear with the atmospheric pressure. Above and behind the pharyngeal opening is limited by the tubal torus. At the bottom this torus continues into a thin salpingopharyngeal fold. The pharyngeal recess is behind the torus tubarius. Next to each opening of the auditory tube lies the tubal tonsil, which is an organ of the immune system.

The entrance into the larynx is bordered on the top by the epiglottis, at the sides — by the aryepiglottic folds, and at the bottom — by the arytenoid cartilage. Between the inner surface of the larynx and the aryepiglottic cartilage, on each side, there is a recess called the p i r i f o r m recess.
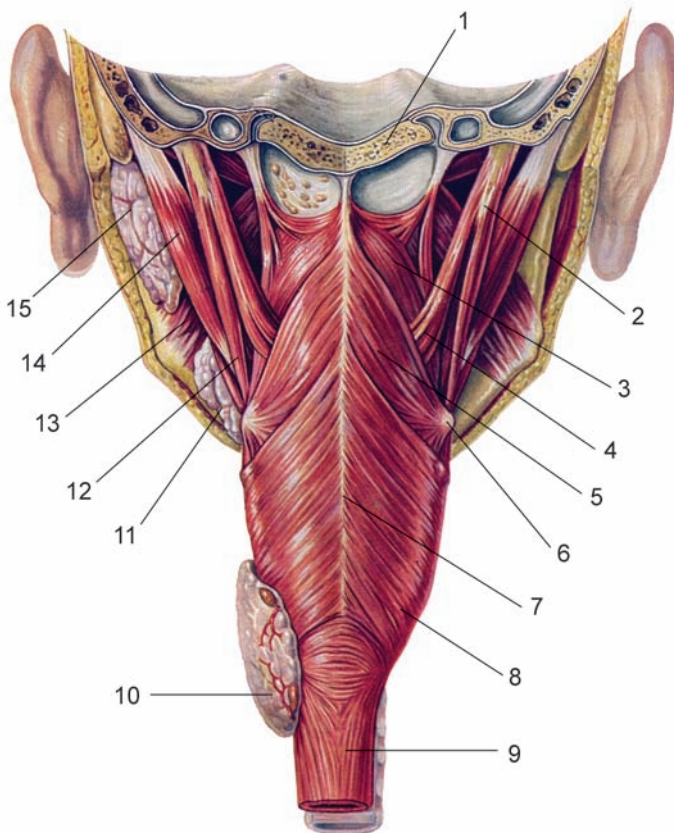
Fig. 126. Muscles of pharynx; Posterior aspect. Frontal cut. Posterior part of cranium is removed.

1 — basilar part of occipital bone; 2 — styloid process; 3 — superior constrictor; 4 — stylopharyngeus; 5 — middle constrictor; 6 — greater horn of hyoid bone; 7 — pharyngeal raphe; 8 — inferior constrictor; 9 — oesophagus; 10 — left lobe of thyroid gland; 11 — submandibular gland (salivary); 12 — stylohyoid muscle; 13 — medial pterygoid; 14 — posterior belly of digastric; 15 — parotid (salivary) gland.

The wall of the pharynx consists of the mucosa, a thick submucosa, the muscularis and the adventitia. The mucosa is lined with pseudostratified ciliary epithelium. In the regions of the oropharynx and laryngopharynx the mucosa has striated squamous epithelium, situated on the lamina propria with a high content of elastic fibers. The submucosa of the nasopharynx and oropharynx is thickened and forms a fibrous plate called the p h a r y n g o b a s i l a r   f a s c i a (fáscia pharyngobasiláris). At the level of the laryngopharynx the submucosa consists of loose fibrous connective tissue and contains a large number of glands.

The mucosa of the pharynx consists of five striated muscles, which include three pharyngeal constrictors and two longitudinal elevator muscles.

The s u p e r i o r   c o n s t r i c t o r muscle of the pharynx (m. c o n s t r í c - t o r   p h á r y n g i s   s u p é r i o r) originates on the medial lamina of the pterygoid process of sphenoid bone and the pterygomandibular raphe of the fibrous plate, stretched between the sphenoid bone and the mandible. Its fibers stretch downward and to the back, and connect with the muscle fibers of the opposite side (table 17).

Table 17. Muscles of the Pharynx.

Muscle	Origin	Insertion	Action	Innervation
Pharyngeal constrictors:				
Superior constrictor	Medial pterygoid lamina, pterygo-mandibular liga-ment, mandible and root of tongue	Posterior side of pharynx (accretes with analogous muscle of oppo-site side	Constricts the pharynx	Branches of pharyngeal plexus
Middle constrictor	Greater and lesser horns of hyoid bone	Same as above	Same as above	Same as above
Inferior constric-tor	Lateral surfaces of thyroid and cricoid cartilages	Same as above	Same as above	Same as above
Elevators of pharynx				
Stylopharyngeal	Styloid process of temporal bone	Lateral wall of pharynx	Raises pharynx upward	Branches of glosso-pharyngeal nerve
Salpingo-pharyngeal	Inferior surface of cartilage of the au-ditory tube and its pharyngeal open-ing	Same as above	Raises pharynx upward and later-ally	Branches of pharyn-geal plexus

The m i d d l e   c o n s t r i c t o r muscle of the pharynx (m. c o n s t r í c - t o r   p h á r y n g i s   m é d i u s) originates from the greater and lesser horns of the hyoid bone. Its muscle fibers spread out upward and downwards, connecting with muscle fibers of the opposite side on the posterior wall of the pharynx. The upper edge of the middle constrictor overlaps the superior constrictor.

The i n f e r i o r   c o n s t r i c t o r muscle of the pharynx (m. c o n - s t r í c t o r   p h á r y n g i s   i n f é r i o r) originates from the lateral surface of the thyroid cartilage plate and from the cricoid cartilage. Its fascicles

spread out upwards, downwards and horizontally, covering the lower edge of the middle constrictor, and are connected to analogous fascicles of the opposite side. The lower fascicles of this muscle pass onto the esophagus. The accretion of the left and right fascicles of the constrictor muscles on the posterior wall forms the p h a r y n g e a l r a p h e. The constrictor muscles narrow the lumen of the pharynx.

The longitudinal group of muscles of the pharynx includes two muscles. The s t y l o p h a r y n g e u s muscle (m. s t y l o p h a r ý n g e u s) originates from the styloid process of temporal bone. It stretches downward and medially and enters the wall of the pharynx approximately between the superior and middle constrictors. During contraction it raises the pharynx together with the larynx. The p a l a t o p h a r y n g e u s muscle (m. p a l a t o p h a r ý n g e u s) originates inside the posterior wall of the pharynx and from the posterior edge of the thyroid cartilage plate. It stretches upward and is inserted into the palatine aponeurosis. Part of its fascicles attach on the hook of the sphenoid bone, and another part — to the internal cartilage plate of the auditory tube, forming the s a l p i n g o p h a r y n g e u s muscle. The palatopharyngeus muscle brings the palatopharyngeal arches toward each other and raises the lower part of the pharynx and larynx.

Swallowing (deglutition). When the food bolus touches the palate, the root of the tongue and the posterior wall of the pharynx, it triggers receptors of these regions. A nerve impulse travels along the glossopharyngeal nerves to the deglutition center of the medulla oblongata. Neurons of this center send impulses along the trigeminal, glossopharyngeal, vagus and hypoglossal nerves to the muscles of the oral cavity, tongue, pharynx, oesophagus and larynx. Coordinated contraction of these muscles promotes the swallowing of food. The act of swallowing consists of a voluntary phase (0.7–1.0 seconds) and an involuntary phase (4–6 seconds). Deglutition is conducted through the following consecutive phases:

1. The muscles of the soft palate contract, raising the palatine velum, and the apertures of the auditory tubes become open.

2. The palatine velum pushes against the vault of the pharynx, secluding the nasopharynx.

3. During contraction of the muscles of the diaphragm of the mouth the larynx is shifted up and forwards, such that the epiglottis closes off its entrance.

4. Contraction of the styloglossus and hyoglossus muscles shifts the root of the tongue back, and the food bolus gets pushed through the fauces. Contraction of the palatoglossal muscles breaks off the part of the bolus, which is in the oropharynx, from the part, which remains in the mouth.

5. When the food enters the oropharynx, the longitudinal muscles raise the pharynx, as if pulling it over the bolus.

6. Consecutive contraction of the constrictor muscles (from top to bottom) pushes the food bolus into the oesophagus.

OESOPHAGUS

The oesophagus (esophágus) is a hollow tubular organ connecting the pharynx and the stomach, which serves to conduct food masses (Fig. 127). The length of an adult esophagus is 25–27 cm. In its upper part it is somewhat flattened in the frontal plane, and in the lower part (beneath the level of the jugular notch) it is shaped like a flat cylinder. The esophagus begins at the level of C5–C7 vertebrae and enters the stomach at the level of T9–T12 vertebrae. Its lower boundary is usually 1–2 vertebrae higher in women than in men.

The c e r v i c a l   p a r t of the oesophagus is 5–7 cm long. It is surrounded by loose connective tissue, which passes on the bottom into the adipose tissue of the posterior mediastinum. The front of the cervical part lies against the membranous wall of the trachea, with which it is tightly connected by loose fibrous connective tissue. The left laringeus recurrens nerve goes up along the front surface of the oesophagus, while the right laringeus recurrens nerve passes along its right side behind the trachea. In the back the oesophagus lies against the spine and the long muscles of the neck, which are covered by the vertebral lamina of the cervical fascia. On each side of the cervical part of the oesophagus are nerve and blood vessel bundles (the common carotid artery, internal jugular vein, vagus nerve).

The t h o r a c i c   p a r t of the oesophagus is 16–18 cm long. In front of it lies the membranous wall of the trachea, lower down are the arch of aorta and the beginning of the main left bronchus. Between the posterior wall of the trachea, the left main bronchus and the oesophagus lie the muscle and connective tissue fascicles of the inconstant b r o n c h o e s o p h a g e a l   m u s c l e and l i g a m e n t. Below this point the oesophagus passes behind the pericardium in the region corresponding to the left ventricle.

Behind the thoracic part of the oesophagus is the spinal column (down to the level of T3–T4 vertebrae). Below this level the posterior surface of the oesophagus lies against the thoracic duct and, still lower, the azygos and hemiazygos veins.

The interaction between the oesophagus and aorta is complex. In the beginning the aorta lies against the left surface of the oesophagus, and then passes between it and the spine, while in the lower region the

thoracic part of the oesophagus is situated in front of the aorta.

Along the sides of the lower thoracic part of the oesophagus lie the vagus nerves. The left nerve passes along the left side closer to the front, and the right — closer to the posterior surface. At the level of T2–T3 vertebrae the right surface of the oesophagus is often covered with the right mediastinal pleura. The right lower third of the thoracic part of the oesophagus and the right mediastinal pleura are connected with the pleuro-esophageal muscle.

The abdominal part of the oesophagus, 1.5–4.0 cm long, passes obliquely down and leftward from the oesophageal hiatus of the diaphragm to where it enters the stomach. In the abdominal cavity the oesophagus adjoins the left peduncle of the diaphragm and the caudate lobe of the liver. The left vagus nerve is situated on the front wall of the oesophagus and the right nerve — on its posterior wall. In 80 percent of cases the abdominal part of the oesophagus is covered with peritoneum from all sides, while in 20 percent its posterior surface lacks the peritoneal covering.

Although the passage of the oesophagus is more or less linear, it does form curves. It is situated along the median line down to the C6 vertebra and then forms a slight curve in the

Fig. 127. Oesophagus. Anterior aspect.

1 — pharynx; 2 — oesophagus (cervical part); 3 — oesophagus (abdominal part); 4 — fundus of stomach; 5 — body of stomach; 6 — greater curvature; 7 — duodenum; 8 — pyloric part of stomach; 9 — diaphragma; 10 — aorta; 11 — aortic arch.

frontal plane to the left. At the level of T2–T3 vertebrae it shifts right toward the median line. The sagittal curve of the oesophagus is situated between C6 and T2 vertebrae (corresponding to the curve of the spine). Beneath the C2 vertebra it forms another curve to the front (due to its adjoining to the aorta). As it passes through the diaphragm the oesophagus leans to the front. The oesophagus has several narrow regions. These nar-

rowings are found in the region of the pharygoesophageal transition, behind the aorta (at the level of the T4 vertebra) and in the region of the esophageal foramen of the diaphragm. There is sometimes a narrowing behind the left main bronchus.

The wall of the oesophagus is made up of four layers: the m u c o s a, s u b m u c o s a, m u s c l a r   l a y e r and the a d v e n t i t i a. The wall is 3.5–5.6 mm thick.

On the inside the oesophagus is lined with non-keratinized stratified squamous epithelium (25–35 layers of epitheliocytes). In the upper third the epithelium is less thick than in the rest of the oesophagus. The basement membrane (0.9–1.1 ìm thick) is fenestrated. The lamina propria mucosa is well developed and forms many papillae, which protrude into the surface epithelium. The upper and, especially, lower parts of the oesophagus have cardiac glands, analogous to the homonymous glands in the stomach (these contain mucous cells and negligible amounts of parietal and endocrine cells). The thickness of the lamina propria notably increases in the zones where cardiac glands are located. The lamina muscularis mucosae gradually thickens from the pharynx to the stomach. The submucosa is well developed and promotes the formation of 4–7 well-expressed longitudinal folds of the mucosa. Along with vessels, nerves, various cells / immune, etc./ the submucosa contains 300–500 multicellular tubuloalveolar mucous glands; these contain solitary endocrine cells.

The muscular layer of the oesophagus in the upper third consists of the skeletal muscle, which gradually gets replaced with smooth myocytes in the middle third. In the lower part the muscularis fully consists of fascicles of the smooth myocytes. Muscle fibers and myocytes are situated in two layers: the internal layer is circular, the external—longitudinal one. In the cervical part of the oesophagus the circular layer is twice as thick as the longitudinal. In the thoracic part both layers are equal, while in the abdominal part the thickness of the longitudinal layer prevails. The muscle layer provides for peristalsis of the oesophagus, as well as the constant tone of its walls. On the outside the oesophagus is lined with adventitia, which is best expressed right above the diaphragm. At the level of the diaphragm the diaphragm is considerably thickened by fibers, which are connected to fascial fibers of the diaphragm. The abdominal part of the esophagus is completely or partially covered with the peritoneum.

STOMACH

The stomach (gáster) is a dilated portion of the digestive tract, located between the oesophagus and duodenum. Food remains in the stomach up to 4–6 hours. During this time it gets mixed and digested with

gastric juices, which contain pepsin, lipase, hydrochloric acid and mucus. The stomach excretes urea and ammonia /its excretory function/. The stomach also performs absorption of sugar, alcohol, water and salt. In its mucosa formation of the antianemia factor /Castle's intrinsic factor/ takes place, which is necessary for binding and absorbing vitamin B_{12}. The shape of the stomach, its position and size constantly change depending on the amount of food consumed, position of the body and constitutional type.

In persons with a brachiomorphic constitution the stomach has the shape of a horn (cone) and is situated almost horizontally. In the dolichomorphic type the stomach is shaped like a stocking and is at first shaped almost vertically, then curving sharply to the right. In persons with a mesomorphic constitution it is shaped like a hook. Its long axis is directed from left to right and from back to front and lies almost in the frontal plane. The stomach is situated in the upper part of the abdominal cavity. Three quarters of the stomach lie in the left subcostal area, and one quarter in the epigastric region. The entrance into the stomach is located to the left of the spine at the level of T10-T11 /sometimes T12/ vertebrae. The exit t from the stomach lies to the right of the spine at the level of T12 or L1 vertebra. Sometimes, especially in heavy persons the stomach and its boundaries may be lowered (gastroptosis).

When it is empty, the stomach is 18–20 cm long and 7–8 cm wide. A moderately full stomach is 24–26 cm long and 10–12 cm wide. The volume of the stomach varies from 1.5 to 4 liters.

The stomach has an a n t e r i o r   w a l l, which faces forward and somewhat up, and a posterior wall, which faces backwards and down. The place where the esophagus enters the stomach is called the cardiac orifice, next to which is the c a r d i a c   p a r t (c a r d i a) of the stomach. To the left the stomach widens, forming the f u n d u s, which, on the bottom, passes into the b o d y of the stomach. Its left convex edge is called the g r e a t e r   c u r v a t u r e, while the right concave edge — the l e s s e r   c u r v a t u r e. The narrowing right part of the stomach, the p y l o r i c   p a r t (p y l o r u s), is subdivided into two parts. It has a wide part — the pyloric cavity, and a narrow part — the p y l o r i c   c a n a l, which passes into the duodenum. The border between the pylorus and the duodenum is marked on the outer surface of the organ by a circular sulcus — the p y l o r u s, which corresponds to the orifice of the pyloric canal and the circular muscle of the p y l o r i c   s p h i n c t e r.

The lesser curvature has a small a n g u l a r   i n c i s u r e at the border between the body on the stomach and the pylorus. On the greater curvature there is a notch between the cardiac part and the fundus.
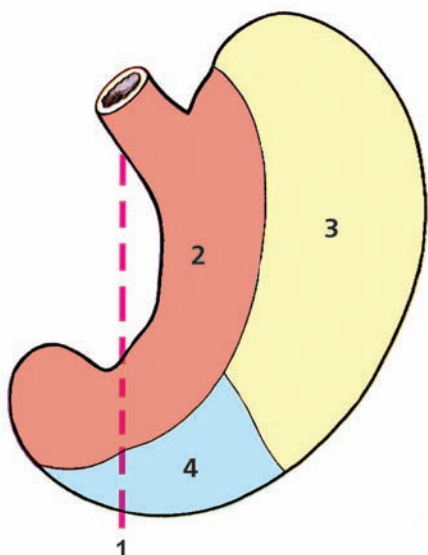
Fig. 128. Areas of conjunction of the front surface of stomach with near organs.

1 — anterior middle line of human body; 2 — area of contact with liver; 3 — with diaphragm; 4 — with the anterior abdominal wall.

The front wall of the stomach (when it is hook-shaped) touches the diaphragm with the cardiac part of its fundus and body, and in the area of the lesser curvature it contacts the visceral surface of the left liver lobe (Fig. 128). A small triangular region of the stomach body is in direct contact with the front abdominal wall. Behind the stomach is the omental bursa, which is a narrow fissure-like space in the abdominal cavity, which separates the stomach from the organs that are located retroperitoneally. Behind the stomach and peritoneum lies the upper pole of the left kidney with the adrenal gland and the pancreas. The posterior surface of the stomach adjoins the transverse colon with its greater curvature, while the upper part of this curvature contacts the spleen.

The stomach may shift during breathing and depending on the content of the neighboring hollow organs (transverse colon). The least mobile zones are the entrance into and exit from the stomach. The stomach is kept in position by fixating ligaments (folds of the peritoneum). The hepatogastric ligament starts at the porta hepatis and passes to the lesser curvature of the stomach. The gastrocolic ligament passes from the greater curvature and left part of the fundus to the hilus of the spleen. The stomach wall consists of the mucosa, submucosa, muscle layer and serosa (Fig. 129). The mucosa is 0.5–2.5 mm thick. It forms 4–5 longitudinal folds along the lesser curvature between the cardiac and pyloric orifices, which facilitated the movement of food masses (passage of the stomach). In the area of the fundus and body there are transverse, longitudinal and oblique folds, which constantly transform depending on physiological conditions. At the transition between the pyloric canal and duodenum the mucosa forms a circular fold — the pyloric screen.

The surface of the mucosa is made up of g a s t r i c a e r e a s (Fig. 130). These fields are of polygonal shape, vary in size from 1 to 6 mm,
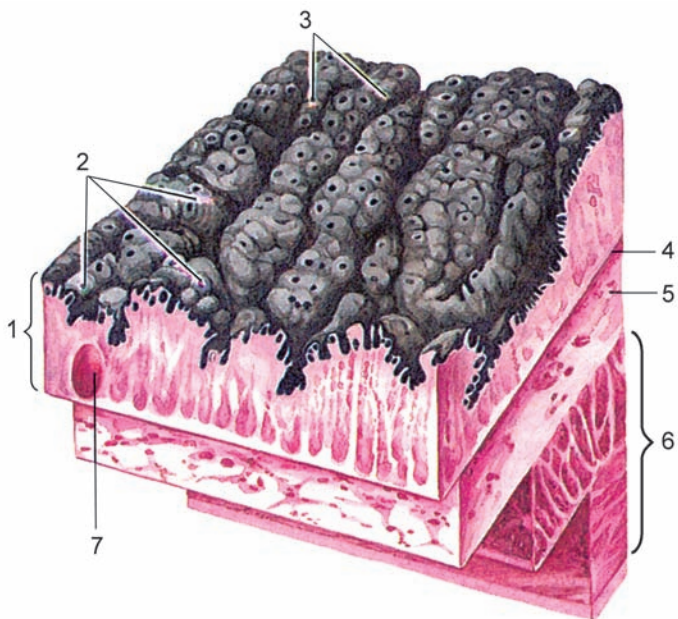
Fig. 129. Structure of stomach wall (acc. to V.Bargman).

1 — mucous membrane; 2 — gastric areas; 3 — gastric pits; 4 — muscularis mucosae; 5 — submucosa; 6 — muscular coat; 7 — solitary lymphoid nodule.
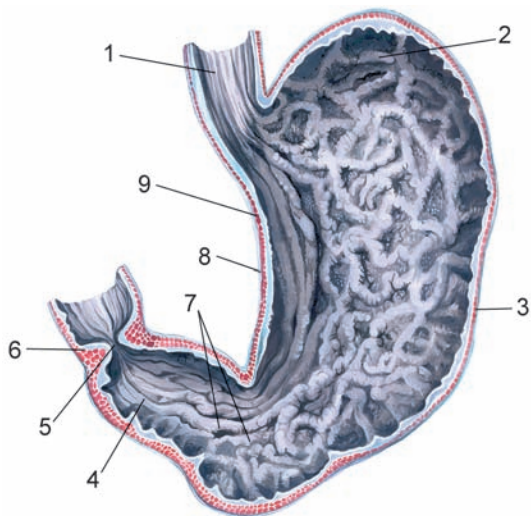
Fig. 130. Folds of mucous membrane of stomach
(longitudinal section, internal surface of posterior paries).

1 — oesophagus; 2 — fundus of stomach; 3 — greater curvature; 4 — pyloric part; 5 — pyloric orifice; 6 — sphincter of pylorus; 7 — gastric folds; 8 — body of stomach; 9 — lesser curvature.

and give the inside surface of the stomach a granular appearance. Deep furrows separate these fields from each other. On the surface of the gastric fields there are many indentations called g a s t r i c p i t s, into which the excretory ducts of glands open. Mm2 of mucosa has approximately 60 gastric pits. The m u c o s a is covered by simple columnar epithelium. The apical part of the cells is filled with granules. The basal part of epitheliocytes contains an ovoid nucleus and endoplasmic reticulum. The Golgi complex is located above the nucleus. The lamina propria mucosae contains vessels, nerves, lymphoid nodules, various cells (immunocytes, smooth myocytes, etc.), as well as gastric glands.

G a s t r i c g l a n d s are simple tubular unbranched glands. They are subdivided into proper (fundic), pyloric and cardiac glands. The fundi of the glands are situated deep in the lamina propria. The gland fundus (body) passes into the neck (excretory duct) followed by an isthmus. Isthmuses of 4–5 glands open into one gastric pit. The general number of gastric glands is approximately 35 million.

The f u n d a l (main, proper) g l a n d s are 0.65 mm long and 30–50 µm in diameter. The length of these glands is 2–3 times greater than the depth of the gastric pit. Their excretory duct makes up a third of the length. The fundic glands are fixed within the lamina propria mucosae, in the region of the excretory duct, by connective tissue. The fundic glands are subdivided into chief (peptic, enzyme-producing) cells, mucous cells, mucocytes and endocrine cells.

P r i n c i p a l c e l l s (granulocytes) have a cylindrical shape. They contain granules of protein secretion in the apical part of the cytoplasm. The plasma membrane in the apical region has many short microvilli. These cells have well-developed Golgi complex and rough endoplasmic reticulum, and a large number of ribosomes. Beneath the Golgi complex lies the nucleus.

P a r i e t a l c e l l s (granulocytes) are larger than chief cells. They have a round or ellipsoid nucleus and many mitochondria. It is characteristic of them to have branching intracellular secretory canaliculi, which open into the gland lumen. The canaliculi lumen contain an inactive hydrochloric acid and protein complex, which his synthesized by these cells. Once this complex is excreted onto the mucosa, it breaks down into a protein and hydrochloric acid.

M u c o u s c e l l s are smaller in size than chief and parietal granulocytes. They are of elongated shape, the nucleus located in their basal part with the organelles above. A relatively small amount of mucous granules is found in the apical region of the cytoplasm. The Golgi complex and endoplasmic reticulum are weakly developed and there are considerable numbers of mitochondria.

Endocrine cells of gastric glands have certain morphological and biochemical peculiarities. More than 10 types of these cells are described. Enterochromaffin (EC-) cells produce serotonin. Enterochromaffin-like (EC-) cells secrete histamine. A-cells synthesize glucagons, D-cells — somatostatin, D.I-cells — vasoactive intestinal peptide, P-cells — bombesin, etc. A common characteristic for endocrine cells of different types is the presence of secretory granules in the basal part of the cell and the Golgi complex above the cell. The secretion of these cells is excreted through the basement and basolateral part of the cell membrane into the extracellular space.

P y l o r i c   g l a n d s are found in the pyloric region on an area of 4.4–5.5 cm^2 at the lesser curvature and 4 cm^2 at the greater curvature. Anatomical boundaries of the pyloric region and zones where these glands are located do not coincide. These glands may be found in the fundus in the shape of wide cords. The pyloric glands consist mostly of mucocytes, between which there are parietal and endocrine cells. These glands do not contain chief cells.

C a r d i a c   g l a n d s are found in the cardiac region of the stomach. The extension of the area they occupy may vary in individuals. They contain mainly mucocytes, but contain also parietal and endocrine cells.

The l a m i n a   m u s c u l a r i s   m u c o s a e is formed by three layers of smooth myocytes: the internal and external layers have a circular orientation, while the middle layer is longitudinal. Solitary thin muscle fascicles may be found in the lamina propria mucosae. Contraction of smooth muscle elements promotes formation of folds on the mucosa and secretion by the glands.

The s u b m u c o s a is well developed. Its loose connective tissue is rich in elastic fibers and contains vessels, nerves, many lymphoid nodules and various cell elements.

The t u n i c a   m u s c u l a r i s is formed my smooth muscle tissue and is made up of three layers (Fig. 131). The external layer is oriented longitudinally, the middle layer is circular, and the internal layer has an oblique orientation. Longitudinal muscle fascicles are located mainly close to the curvatures of the stomach, but some may also be found in the pyloric region. A thickening in the circular layer in the cardiac region forms the cardiac sphincter. Its thickness correlates to the shape of the stomach. The sphincter is thicker and narrow in a stalking-shaped stomach and thinner and wider in a horn shaped stomach. The circular layer is best developed in the pyloric region, where it forms the pyloric sphincter (3–5 mm thick). When it contracts, the passage between the stomach and duodenum becomes closed. Beneath the circular muscles there are oblique muscle fascicles. The obliquely oriented myocytes pass over the cardiac region to the left of

the cardiac orifice and go downwards and to the right through the anterior and posterior walls of the stomach towards the greater curvature. Between the muscle layers there is a nervous plexus. The muscles of the stomach support its tone, create a constant pressure inside the stomach and mix food masses (peristalsis). The result of mixing of food with gastric juices is a thin mixture called chyme, which is passed into the duodenum in small portions.

On the outside the stomach is covered by the peritoneum (intraperitoneal position). The serous tegument is absent only on narrow strips along the lesser and greater curvatures. The serosa is separated from the muscularis by the subserosa.

I n n e r v a t i o n of the stomach: the gastric plexus is formed by the vagus nerve and sympathic nerve fibers from the celiac plexus.

B l o o d   s u p p l y: left gastric artery /from the coeliac trunk; right gastric a./from the hepatic artery, right gastro-omental artery /from the gastroduodenal a./, left gastro-omental artery and short gastric arteries /from the splenic a./. The gastric and gastro-omental arteries anastomose, forming an arterial circle around the stomach.
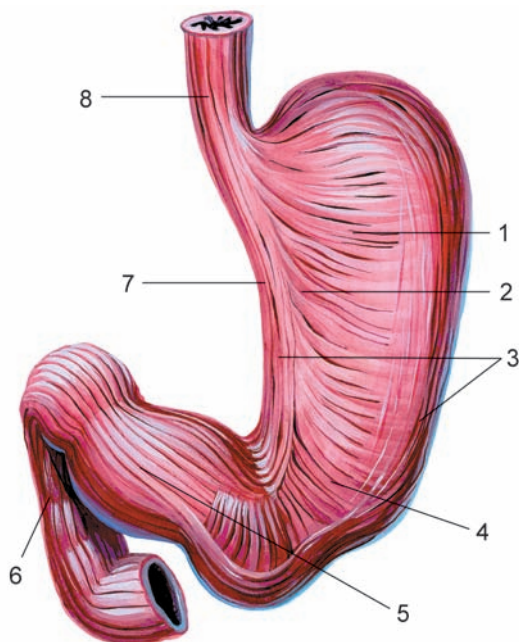
Fig. 131. Muscular coat of stomach. Circular layer and oblique fibers (part of circular layer is removed).

1 — circular layer; 2 — oblique fibers; 3 — longitudinal layer; 4 — body of stomach; 5 — pyloric part; 6 — duodenum; 7 — lesser curvature; 8 — oesophagus.

Venous outflow: left and right gastric vv., left and right gastro-omental veins /enter the portal vein/.

Lymph outflow: right and left gastric, right and left gastro-omental, pyloric lymph nodes.

SMALL INTESTINE

The small intestine (intéstinum ténue) is a part of the alimentary tract located between the stomach and the large intestine. Together with the large intestine it forms the longest part of the digestive system. The small intestine is divided into the d u o d e n u m, j e j u n u m and i l e u m. Inside the small intestine chyme (liquefied food mass), which has been partially digested by saliva and gastric juice, undergoes processing by bile, and intestinal and pancreatic juices. Within its lumen the process of digestion becomes completed and products of digestion are absorbed. Indigestible remnants of food move towards the large intestine. The small intestine also has an important endocrine function. Endocrinocytes, which are found in its epithelium and glands, produce bioactive substances (secretin, serotonin, motilin, etc.).

The small intestine begins at the level between the bodies of T12 and L1 vertebrae, and ends in the right iliac fossa. It is situated in the gastric region (middle section of the abdomen), and reaches the inlet into the minor pelvis. Its length in an adult is 5–6 meters. It is longer in men than in women. In a live person the small intestine is longer than in a cadaver, due to muscle tone. The duodenum is 25–30 cm long; the jejunum takes up 2.0–2.5 m (2/5 of the whole small intestine); and the ileum is approximately 2.5–3.5 m long. The diameter of the small intestine is 3–5 cm. It tends to decrease in the direction of the large intestine. Unlike the ileum and jejunum, which form the mesenteric part of the small intestine, the duodenum does not have a mesentery.

Duodenum

The duodenum is the beginning part of the small intestine. It is situated on the posterior wall of the abdominal cavity. The duodenum is a continuation of the pylorus. It ends in the duodenojejunal curvature, which lies near the left edge of the L2 vertebra. Usually, the duodenum has the shape of a horseshoe, which rounds the head of the pancreas. The duodenum consists of the superior, descending, horizontal and ascending parts.

The s u p e r i o r   p a r t extends from the pylorus to the right and backwards, forming the s u p e r i o r   d u o d e n a l   f l e x u r e. If the stomach is full, the upper part of the duodenum lies almost in a sagittal position. When

the stomach is empty it lies transversely. The length of the superior part is 4–6 cm. Its upper surface adjoins the posterior part of the quadrate lobe of the liver and crosses the proper hepatic artery and the common hepatic duct. At the bottom it touches the top of the head of the pancreas and transverse colon. Behind the superior part, inside the hepatoduodenal ligament lies the common bile duct, proper hepatic artery and portal vein.

The d e s c e n d i n g p a r t of the duodenum begins at its superior flexure, at the level of the L1 vertebra, and extends downwards along the right edge of the vertebral column. The descending part ends at the level of the third lumbar vertebra with as a sharp turn to the left, forming the inferior duodenal flexure. The length of the descending part is 8–10 cm. Behind it lies the hilus of the right kidney and the upper part of the ureter. The medial side of the descending part adjoins the inferior vena cava and, in the place of transition between the superior and descending parts, the right suprarenal gland.

In the front the descending part is covered by the peritoneum and is crossed by the root of the transverse colon. On the left it adjoins to the head of the pancreas and is firmly accreted with its capsule. Between the descending part and the head of the gland passes the end part of the common bile duct. Also passing through this space are the anatomized superior and inferior pancreaticoduodenal arteries.

The h o r i z o n t a l p a r t of the duodenum begins from its lower flexure. It extends horizontally to the left at the level of the L3 vertebra, then turns upward and continues into the ascending part. At this level it crosses the superior mesenteric artery and vein. Behind the horizontal part lie the inferior vena cava (right) and aorta (left). The anterior surface of the horizontal part is covered by the peritoneum and adjoins the loops of the small intestine.

The a s c e n d i n g p a r t begins in the place where the superior mesenteric artery and vein pass from beneath the lower margin of the pancreatic gland onto the front surface of the duodenum. The ascending part ends near the left edge of the L2 vertebra body with a sharp flexure downwards, forwards and to the left (d u o d e n o j e j u n a l f l e x u r e). This flexure is fixed to the diaphragm by the s u s p e n s o r y m u s c l e a n d l i g a m e n t o f t h e d u o d e n u m (Treiter's muscle and ligament). Behind the ascending part lies the aorta, and in front to it — the parietal peritoneum.

Jejunum and Ileum

The jejunum and ileum form the mesenteric part of the small intestine. They form 14–16 loops, which are located primarily in the umbilical region. Part of its loops lies in the lesser pelvis. Loops of the jejunum are situated mainly in the upper left section, and loops of the ileum — in the
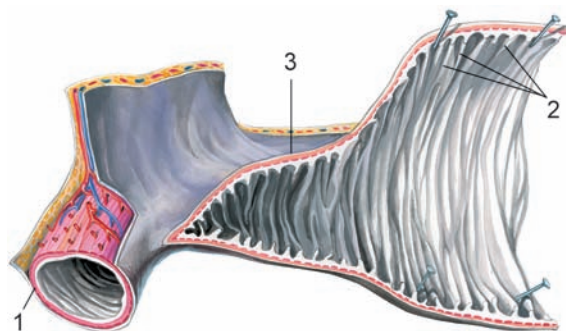
Fig. 132. Relief of mucous membrane of small intestine. Region of intestine is longitudinally opened.

1 — wall of intestine; 2 — circular folds; 3 — serous coat.

lower right section of the abdominal cavity. There is no strict anatomical border between these two parts of the small intestine. In the front intestinal loops are covered by the greater omentum; in the back — by the parietal peritoneum, which lines the right and left mesenteric sinuses. The jejunum and ileum are fixated on the posterior abdominal wall by the mesentery, the root of which attaches to the right iliac fossa.

The wall of the small intestine is formed by the mucosa, submucosa, m u s c u l a r   l a y e r and external lining. The mucosa is characterized by circular folds (Fig. 132). Their numbers reach 600–700. These folds take up more than two thirds of the circumference of the intestine. Their formation is promoted by the submucosa, and their sizes decrease in the direction of the large intestine. The average height of the circular folds is 8 mm. They increase the area of the mucosa by 3 times. The mucosa of the superior and descending parts of the duodenum also forms longitudinal folds. The largest of these is located on the medial wall of the descending part. Situated in the lower part of this fold is the m a j o r   d u o d e n a l   p a p i l l a of the duodenum (Vater's papilla). On this papilla is the common opening of the common bile duct and the pancreatic duct. Above this papilla, situated on the longitudinal fold, is the m i n o r   d u o d e n a l   p a p i l l a of duodenum. On it are additional openings of the pancreatic duct.

The m u c o s a of the small intestine has numerous protrusions called i n t e r s t i n a l   v i l l i (Fig. 133), the number of which reaches 4–5 millions. One square millimeter of the mucosa in the duodenum and jejunum carries 22–40 villi, and in the ileum — 18–31 villi. The average length of a villus is 0.7 mm. Their size tends to decrease in the direction of the large intestine. Villi may be foliate, lingual and fingerlike. The first two classes are orientated perpendicularly to the intestinal tube. The longest villi (approximately 1 mm)

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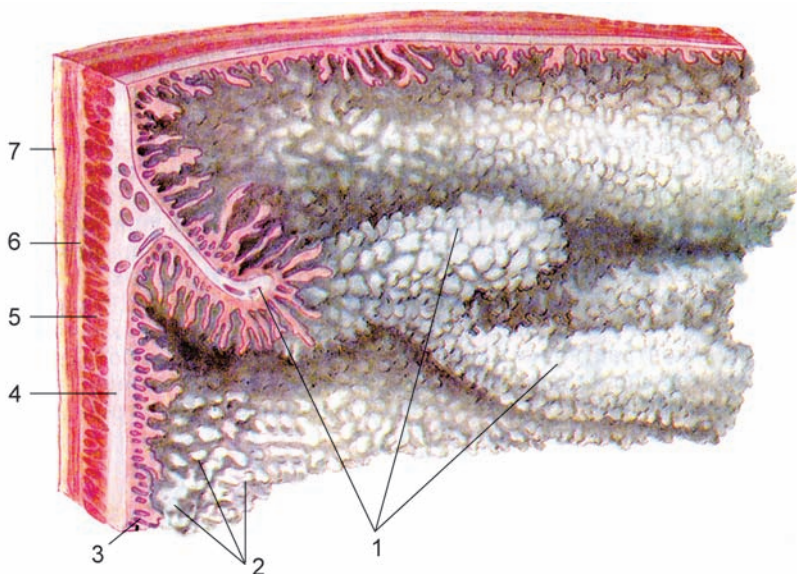
Fig. 133. Relief of mucous membrane of small intestine. Surface of mucous cover and layers of intestinal wall.

1 — circular folds; 2 — intestinal villi; 3 — mucous membrane; 4 — submucousa; 5 — circular layer of muscular coat; 6 — longitudinal layer of muscular coat; 7 — serous coat.

are mostly foliate. The beginning part of the jejunum contains primarily lingual villi. In more distal parts the villi become fingerlike. Their length decreases to 0.5 mm. The spaces between the villi measure 1–3 mm. The villi are formed by loose connective tissue, which is covered with epithelium. Inside them there are a lot of smooth myocytes, reticular fibers, lymphocytes, plasma cells and eosinophils. In the center each villus contains a lymphatic capillary (central lacteal), which is surrounded by blood vessels.

The surface of the mucosa, including the villi (Fig. 134), is covered with simple columnar epithelium, situated on a basal membrane. The majority of epitheliocytes (approximately 90 percent) are columnar enterocytes, characterized by a brush border on their apical membrane. The brush border is formed by microvilli. On the surface of the microvilli is the glycocalyx. The major function of columnar epithelium is absorption. The epithelial lining also contains numerous goblet cells, which secrete mucus. Approximately 0.5 percent of all epithelial cells are endocrinocytes. Inside the epithelium there are also lymphocytes, which permeate the stroma of villi and the basement membrane.

In the spaces between the villi are the opening of intestinal glands (Lieberkuhn's crypts) (Fig.135). These are tubular glands with a round or

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ovoid ostium. The glands are 0.25 – 0.5 mm long and 0.07 mm in diameter. One square meter of mucosa contains 80–100 intestinal glands. Their wall is formed by one layer of epitheliocytes, situated on a basement membrane. Among epithelial cells there are columnar epitheliocytes with brush borders, goblet cells, endocrinocytes, columnar cells without a brush border (stem cells) and Paneth's granular cells. Stem cells are the source of regeneration of the intestinal epithelium. Endocrinocytes produce serotonin, cholecystokinin, secretin, etc. Paneth's granular cells secrete lysosomal enzymes (erepsin).

Fig. 134. Structure of intestinal villi.

1 — intestinal epitheliocytes (columnar cells); 2 — goblet cell; 3 — central lymphatic capillary; 4 — arteriole; 5 — venula; 6 — blood capillaries.

The l a m i n a p r o p r i a of the small intestine mucosa contains a considerable amount of reticular fibers, which form a thick network. Inside the lamina propria there are always eosinophils, lymphocytes and plasma cells. It also contains a large amount of s o l i t a r y l y m p h o i d n o d u l e s (in children there are 3–5 thousand). In the mesenteric part of the small intestine, especially in the ileum, there are 40–80 a g g r e g a t e d l y m p h o i d n o d u l e s called P e y e r's p a t c h e s. Plaques are located primarily along the counter-mesenteric side of the intestine and have an oval shape (see «Organs of hemopoiesis and the immune system»).

The m u s c u l a r i s m u c o s a of the small intestine is about 40 mm thick. It has circular and longitudinal layers. Some individual myocytes separate off from the muscularis mucosa into the lamina propria.

The s u b m u c o s a of the small intestine contains lobules of adipose tissue. Inside it there are nerves and blood vessels, and various cell elements. The submucosa is also penetrated by groups of large lymph nodules. The submucosa of the duodenum also contains the secretory parts of the duodenal (Brunner's) glands. Duodenal glands are compound tubular glands, which produce mucous secretion. Their ostiums are located between villi, on the surface epithelium or into the intestinal glands of the

Fig. 135. Intestinal crypt
(acc. to F.Shterr).

1 — intestinal epitheliocyte with striated margins (columnar cell); 2 — goblet cell; 3 — cell with acidophillic granules

duodenum. The density of the duodenal glands and their sizes are greater in the beginning part of the duodenum than in its end.

The muscular coat of the small intestine consists of two layers. The internal (circular) layer is thicker than the external longitudinal one. The orientation of muscle fascicles is not strictly circular or longitudinal, but may be defined as spiral. In the external layer the volutions of the spiral are longer than in the internal layer. Between the two muscle layers there is loose connective tissue, which contains the nervous plexus and vessels.

The s e r o s a is situated over a subserosa layer. It covers the small intestine from all sides, except for the duodenum, which is covered only from the front.

I n n e r v a t i o n: duodenum — fibers from the vagus nerve and the gastric, hepatic and superior mesenteric plexuses; jejunum and ileum — fibers of the vagus nerve and superior mesenteric plexus.

B l o o d s u p p l y: duodenum — anterior and posterior superior pancreaticoduodenal arteries (from gastroduodenal arteries), inferior pancreaticoduodenal artery (from superior mesenteric artery). Jejunum and ileum — jejunal and ileal arteries (from superior mesenteric artery).

V e n o u s o u t f l o w: along homonymous veins into the portal vein.

L y m p h o u t f l o w: duodenum — pancreaticoduodenal, superior mesenteric, celiac and lumbar lymph nodes. Jejunum and ileum—mesenteric and ileocolic (from end part of ileum) lymph nodes.

LARGE INTESTINE

The large intestine (intéstinum crássum) continues from the small intestine. It is divided into the caecum, colon and rectum. The colon, in turn, consists of the ascending, transverse, descending and sigmoid colons. The main function of the large intestine is elimination of feces and absorption of water and vitamins. Its length is approximately 160 cm. In live

persons this length is somewhat greater due to considerable elasticity of tissues. The length of the caecum makes up about 4.66 percent of the whole large intestine. The ascending colon constitutes approximately 16.17 percent, the transverse colon — 34.55 percent; the descending colon — 13,72 percent; and the sigmoid colon — 29.59 percent. The average diameter of the large intestine is 5–8 cm, and it tends to decrease in the direction of the rectum. An empty large intestine of an adult weights approximately 370 g.

The caecum (caecum) continues from the ileum. It is shaped like a pouch, which hangs downward. Occasionally the cecum can be cone-shaped. Its length is 4–8 cm.

Fig. 136. Caecum with appendix. Anterior wall is removed.

1 — ileal orifice; 2 — ileocaecal valve; 3 — ascending colon; 4 — ileum; 5 — orifice of vermiform appendix; 6 — vermiform appendix; 7 — caecum.

Its posterior surface adjoins the iliac and major psoas muscles. The front surface adjoins the anterior abdominal wall. The caecum does not have a mesentery, but is covered with peritoneum from all sides (intraperitoneal position). From the caecum extends the v e r m i f o r m   a p p e n d i x, which pertains to the immune system. The appendix usually begins on the posteromedial surface of the cecum (Fig. 136). Its length varies between 2 and 20 cm (on average 8 cm). Its diameter is 0.5–1.0 cm. The appendix may begin on any other side of the caecum, and may extend in different directions. Usually it is situated within the right iliac fossa, its free end is turned down and medially, reaching the pelvic brim and sometimes entering the lesser pelvis. It can also be situated behind the cecum (retrocecal position) or may lie retroperitoneally. Normally the appendix has a mesentery, which connects it to the wall of the cecum and the end part of the ileum.

The ascending colon (cólon ascéndens) is 18–20 cm long. Its position may vary. Its posterior wall occupies the right lateral section of the

posterior abdominal wall. The ascending colon extends upward, passing first in front of the quadrate muscle of the abdomen, and then over the right kidney, which is situated retroperitoneally. Near the inferior /visceral/ surface of the liver the ascending colon turns forward and to the left, forming the r i g h t   c o l i c   (h e p a t i c)   f l e x u r e.

The transverse colon (cólon transvérsum) usually passes across the abdomen in a downward arch pattern. It begins in the right subcostal region, at a level of the tenth costal cartilage, and ends in the left subcostal region. Its length is on average 50 cm. (ranging between 40 and 50 cm). Within the left subcostal region, at a level of the ninth costal cartilage, the transverse colon forms the l e f t   (s p l e n i c)   f l e x u r e, which is shaped like a sharp angle. The transverse colon is covered from all sides by the peritoneum and has a mesentery, which fixes it to the posterior wall of the peritoneal cavity. The anterior surface of the transverse colon is fixed to the greater curvature of the stomach and the upper part of the duodenum by the gastrocolic ligament, which is formed by the upper part of the greater omentum.

The top of the right colic flexure adjoins to the liver, and the left colic flexure — to the stomach and spleen. Below the transverse colon lie loops of the small intestine; behind it lie the duodenum and pancreas. When the stomach is empty the front surface of the transverse colon adjoins the anterior abdominal wall, and when it is full, the colon is pushed back.

The descending colon (cólon descéndens) begins at the left colic flexure and continues into the sigmoid colon at the level of the iliac crest. The average length of the descending part is 25 cm. The descending colon projects within the left lumbar region. The front surface of the descending colon adjoins the anterior abdominal wall. To its right lie the loops of the jejunum, and to its left — the left abdominal wall. The descending colon is covered by the peritoneum from the front and sides (mesoperitoneal position).

The sigmoid colon (cólon sigmoídeum) begins at the level of the left iliac crest and ends at the level of the promontory, where it continues into the rectum. Its average length is 40–45 cm (ranging between 12 and 84 cm). The sigmoid colon forms 1–2 curves, which adjoin the front surface of the left iliac bone and partially descend into the pelvis. It lies intraperitoneally and has a mesentery. The mesentery allows this colon considerable mobility.

The rectum (réctum) is the terminal part of the large intestine. Its average length is 15 cm, and the diameter varies between 2.5 and 7.5 cm. The rectum consists of the ampoule and the anal canal. The r e c t a l   a m p u l l a   is situated within the lesser pelvis; the anal canal lies inside the perineum. Behind the ampoule are the sacrum and coccyx. In front of it, in males, lie the prostate, urinary bladder, seminal vesicles and ampoules of the right and left deferent ducts; in females there are the uterus and vagina. The a n a l   c a n a l   ends with the a n u s.

The rectum forms flexures in the sagittal plane. The s a c r a l f l e x -
u r e is protrudes backward, and corresponds to the curvature of the sacrum.
The perineal flexure protrudes forward, and is situated inside the perine-
um (in front of the coccyx). Flexures of the rectum within the frontal plane
are inconstant. The upper part of the rectum is covered with the peritoneum
from all sides, the middle part — from only three sides, and the lower part
does not have a serosa lining.

In the region of the anal canal a thickening of muscularis layer forms
the internal (involuntary) anal sphincter. Directly beneath the skin of this
region is the voluntary external anal sphincter, which is one of the muscles
of the perineum. Both sphincters close the anal orifice, opening it during
defecation.

An external characteristic of the large intestine is the presence of three
muscle bands 3–6 mm wide, called taeniae coli (Fig. 137). The f r e e,
m e s o c o l i c and o m e n t a l t a e n i a e c o l i begin near the base of the
appendix and stretch up to the rectum. These bands form as a result of an
unequal distribution of fascicles of the longitudinal muscle layer along the
large intestine, which is thickened within these ribbons.

On the walls of the large intestine there are characteristic fingerlike,
foliate or sack-like o m e n t a l a p p e n d i c e s, which are covered with by
visceral peritoneum. Their average length is 3–4 cm, and their density
increases in the direction of the rectum. These appendages may serve for
amortization during peristalsis and act as fat depots. Because the taeniae
coli are shorter than the actual length of the large intestine, the walls of the
colons form bulging protrusions called haustra.
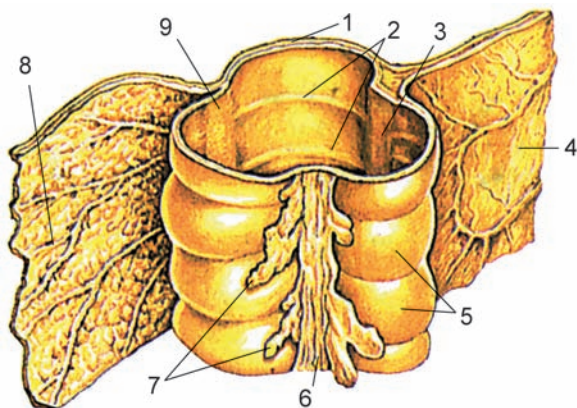
Fig. 137. Fragment of transverse colon.

1 — colonic wall; 2 — semilunar folds of colon; 3 — mesocolic taenia (band); 4 — transverse me-
socolon; 5 — haustrae of colon; 6 — free taenia; 7 — omental appendices; 8 — greater omentum;
9 — omental taenia.

The walls of large intestine are formed by the m u c o s a, s u b m u - c o s a, m u s c u l a r l a y e r and s e - r o s a (adventitia) layers.

The mucosa of the large intestine forms numerous s e m i l u n a r f o l d s. Their height varies between several millimeters to 1–3 cm. These folds are formed by both the mucosa and submucosa layers. In the ampoule of the rectum there are 8–10 longitudinal folds called a n a l c o - l u m n s (Fig. 138). Between them are recesses called a n a l s i n u s e s. Into their walls open the ducts of 5–38 multicellular tubuloalveolar mucous glands, main sections of which are located inside the submucosa of the anal canal. The line drawn through the lower margins of the anal columns and sinuses is called the a n o r e c t a l l i n e.

The mucosa of the large intestine is lined with simple columnar epithelium, which consists of columnar epitheliocytes (absorption cells), goblet cells and endocrinocytes. At the level of the anal canal simple epithelium passes into stratified cuboidal epithelium. Even further, it transforms abruptly into stratified squamous non-keratinizing, and then keratinizing epithelium.

Fig. 138. Rectum.

1 — mucous membrane; 2 — anal columns; 3 — anal sinuses; 4 — anus; 5 — external anal sphincter; 6 — internal anal sphincter; 7 — transverse fold of rectum; 8 — ampula of rectum.

The lamina propria of mucosa is formed by loose connective tissue. Inside it lie 7.5–12 million intestinal glands (crypts of Lieberkuhn), which perform both a secretory and absorptive functions. Approximately 4.5 percent of these glands are found in the cecum; 90 percent are in the colon; and 5.5 percent are in the rectum. The distribution of these glands has certain characteristics, for instance their concentration is higher (by 4–12 percent) at the levels of taeniae coli than between them. The glands situated on top of the semilunar folds and over sphincters tend to be larger. The walls of the glands are lined by simple epithelium, situated on a basement membrane. The epitheliocytes include primarily goblet cells and absorption cells. A constant element of the epithelium are stem cells. In some places there are also endocrinocytes. The number of endocrinocytes

increases in the direction of the rectum. Among them are EC-cells, which produce serotonin and melatonin; A-cells, which produce glucagon; and D^1-cells, which secrete the vasoactive intestinal peptide.

Along the length of the lamina propria of mucosa there are 5.5–6 thousand solitary lymphoid nodules. Also there are lymphoid and mast cells, and sometimes a few eosinophils and neutrophils. The lamina propria contains blood and lymph capillaries and vessels, non-myelinated nerve cells of the intramural nervous plexus and nerve fibers.

The muscularis of the mucosa is formed by two layers of smooth muscles. The internal layer is circular, and the external layer is oblique and longitudinal. Some fascicles of smooth muscle cells (10–30 mm long and 0.2–2.0 mm in diameter) separate from the muscularis and penetrate the lamina propria. Thin muscle fascicles surround intestinal glands and participate in secretion.

The submucosa is formed by loose fibrous connective tissue. It contains solitary lymphoid nodules, the submucosal (Meissner's) plexus, blood and lymph vessels, and mucous glands (at the level of the anal canal).

The muscularis of the large intestine increases in thickness in the direction of the rectum. It is formed by a circular (internal) and a longitudinal (external) layers of muscles. Between these layers lies the myenteric (Auerbach's) plexus, which is formed by ganglion cells, glia cells (Schwann and satellite cells) and nerve fibers. Gangliocytes dominate in zones, which correspond to the taeniae coli. The internal part of the circular muscle layer is the zone of formation of peristaltic waves, which are generated by interstitial (Cajal's) cells, located inside the submucosa, on the border with the muscle layer.

In some places of the large intestine, especially in transition segments between its different parts, the circular layer of the muscularis has thickenings. In these places its lumen may be narrowed, which serves to regulate the passage of chyme, or feces through the intestine during digestion. These muscular thickenings are called c o l o n i c   s p h i n c t e r s. The caeco-ascending sphincter is defined at the upper edge level of the ileocecal valve. The next sphincter (Girsh's sphincter) is situated at the right colic flexure. There are three sphincters in the transverse colon. Near the beginning of the transverse colon is the right (Kennon's) sphincter. The middle transverse and the left Kennon's sphincters are located closer to the left colic flexure. Within the left colic flexure is the Payer's sphincter. Another sphincter is located in the transition between the descending and sigmoid colons. Within the sigmoid colon there are the superior and inferior sigmoid sphincters. The sigmoido-rectal (O'Bernier's) sphincter is situated between the sigmoid colon and rectum.

Between the large intestine and the abdominal walls and neighboring organs there are ligaments, which are formed by folds of the peritoneum. These ligaments form a fixating apparatus, which prevents shifting and ptosis of the colon, and provide passages for blood vessels. The superior ileocecal ligament is a continuation of the mesentery. It attaches to the lower medial surface of the ascending colon. Its base is connected with the peritoneum of the right mesenteric sinus. The mesentericopudendal ligament begins on the mesentery of the terminal part of the ileum. It forms a triangular structure, which descends toward the right edge of the inlet into the lesser pelvis. In the female this ligament continues onto the suspensory ligament of the ovary, and in the males — into the deep ring of the inguinal canal, where it passes into the parietal peritoneum. The left diaphragmaticocolic ligament stretches between the costal part of the diaphragm and the left colic flexure. The bottom of this ligament attaches in the splenic angle between the transverse and descending colons, connecting them to each other. Usually this ligament is accreted with the greater omentum. Other ligaments may be present but are not constant.

I n n e r v a t i o n: colon — branches of vagus nerves and sympathetic fibers from the superior and inferior mesenteric plexuses; rectum — parasympathetic pelvic nerves and sympathetic fibers from the inferior hypogastric plexuses.

B l o o d s u p p l y: colon — superior and inferior mesenteric arteries; rectum — rectal arteries from the inferior mesenteric and iliac arteries.

V e n o u s o u t f l o w: colon — superior and inferior mesenteric veins; rectum — inferior mesenteric vein, inferior vena cava (through medial and inferior rectal veins).

L y m p h o u t f l o w: caecum and appendix — ilieocolic, precaecal and retrocaecal lymph nodes. Ascending, transverse and descending colons — mesentericocolic, paracolic, right, middle and left colic lymph nodes. Sigmoid colon — inferior mesenteric (sigmoid) lymph nodes. Rectum — internal iliac (sacral), subaortal and rectal lymph nodes.

Questions for revision and examination

1. Name the parts of the large intestine and describe each of these parts.
2. Describe the differences between the small and large intestines.
3. Describe the surface relief of mucosa of the rectum, particularly its lower section.
4. Describe the structure of the mucosa of the large intestine.
5. Describe the muscularis of the large intestine. Name its sphincters and ligaments.

LIVER

The liver (hépar) is the largest gland of the body. It is shaped like a flattened and somewhat distorted top of a sphere. Its consistence is that of a soft solid and its color is reddish-brown. In an adult the liver measures 20–30 cm in length, 10–21 cm in width, and between 7 and 15 cm in height. It weights 1400 – 1800 g. The liver participates in the metabolism of proteins, lipids, carbohydrates and vitamins. It also carries out functions of defense and decontamination, bile production and more. During embryogenesis it is an organ of hemopoiesis.

The liver has visceral and diaphragmatic surfaces. The d i a p h r a g - m a t i c   s u r f a c e faces upward and to the front. The v i s c e r a l   s u r - f a c e is flat and is directed downward and to the back (Fig. 139). The inferior border of the liver is sharp, while in the back the liver is rounded.

The liver is located mostly in the subcostal region and, partially, in the epigastrium. It projects onto the skeleton so that its highest point along the right midclavicular line is at the level of the fifth intercostals space. Along the midclavicular line the inferior margin of the liver normally corresponds to the tenth intercostal space. The inferior margin extends forward along the right costal arch. It passes upward from left to right, cross-
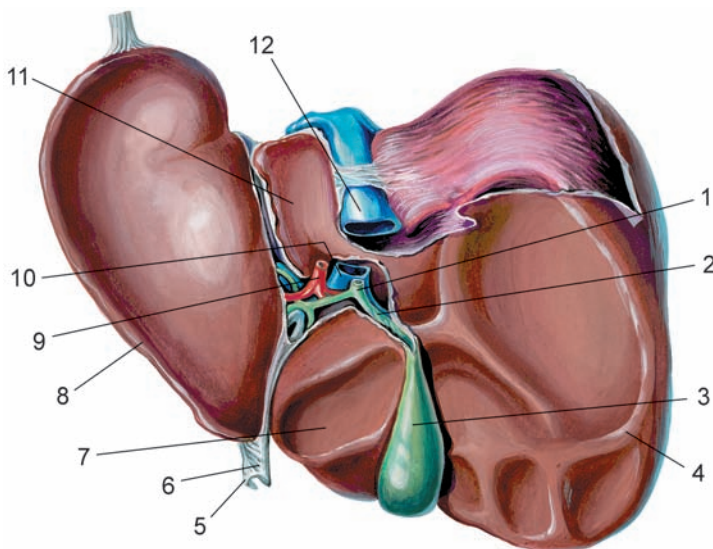
Fig. 139. Liver. Visceral surface.

1 — bile duct; 2 — cystic duct; 3 — gallbladder; 4 — right lobe; 5 — falciforme ligament; 6 — round ligament of liver; 7 — quadrate lobe; 8 — left lobe; 9 — hepatic artery proper; 10 — vena portae hepatis; 11 — caudate lobe; 12 — inferior vena cava.

ing the epigastrium. At the level of the sixth left costal cartilage, to the left of the sternum, the inferior border (left lobe) crosses the costal arch and meets the upper border of the liver. In the back (along the right scapular line) the superior border of the liver projects into the seventh intercostal space, and the inferior border — onto the upper edge of the eleventh rib.

At the top the diaphragmatic surface adjoins the right and, partially, left cupulae of the diaphragm. The front upper part of the liver lies against the costal part of the diaphragm and the front abdominal wall. In the back it adjoins the T10 and T11 vertebrae, peduncles of the diaphragm, abdominal part of the esophagus, the aorta and the right adrenal gland. Below the liver lie the cardia, body and pyloric region of the stomach, superior part of the duodenum, right kidney, right colic flexure and right part of the transverse colon (see «visceral surface of the liver»).

The diaphragmatic surface of the liver has a smooth glistering texture. It is covered with peritoneum, except for a small area on the posterior side. The peritoneum passes onto the liver from the diaphragm, forming duplications, which act as ligaments. The f a l c i f o r m   l i g a m e n t is situated in the sagittal plane; it passes onto the diaphragmatic surface from the diaphragm and the anterior abdominal. Oriented within the frontal plane is the c o r o n a r y   l i g a m e n t, which connects with the posterior end of the falciform ligament. The right and left ends of the coronal ligament spread out, forming the r i g h t and l e f t   t r i a n g u l a r   l i g a m e n t s of the liver. Passing through the free margin of the falciform ligament is the r o u n d   l i g a m e n t, which shape is like a cord. This ligament is the obliterated umbilical vein, which connects the umbilicus and the hilum of the liver. Between the hilum of the liver and the lesser curvature of the stomach and beginning of the duodenum a duplication of peritoneum form the h e p a t o - g a s t r i c and h e p a t o d u o d e n a l   l i g a m e n t s. On the diaphragmatic surface of the left lobe there is a c a r d i a c   i m p r e s s i o n, formed by the heart, which adjoins the liver through the diaphragm.

Anatomically, the liver is divided into the r i g h t   and l e f t   l o b e s, which are divided by the falciform ligament. On the visceral surface the border between these lobes is marked by the groove of the round ligament and the fissure for the ligamentum venosum. The v e n o u s   l i g a m e n t is the obliterated venous duct, which, in the fetus, connected the umbilical vein with the inferior vena cava.

On a visceral surface of the liver, to the right of the round ligament and fissure of the venous ligament is the right sagittal fissure. Towards the front this fissure widens, forming the fossa for gallbladder. In the back it forms the fissure of the inferior vena cava. Between the right and the left sagittal fissures there is a deep transverse fissure, known as the p o r t a   h e p a t i s, or portal fissure. The porta hepatis is situated behind the fossa

for gallbladder and the f i s s u r e for r o u n d l i g a m e n t. It contains the portal vein, hepatic artery, nerves, common hepatic duct (sometimes the right and left hepatic ducts) and lymph vessels.

On the visceral surface of the right liver lobe, there are two small areas called the q u a d r a t e and c a u d a t e l o b e s. The quadrate lobe is situated between the fissure for round ligament, the groove for the inferior vena cava and the portal fissure. The caudate lobe lies between the portal fissure, the fissure fissure for ligamentum venosum and the fissure of the inferior vena cava. The caudate lobe has two pro-cesses. Its c a u d a t e p r o c e s s is directed between the porta hepatis and the groove for the in-ferior vena cava. The p a p i l-l a r y p r o c e s s is directed

Fig. 140. Projections of liver segments (I–VIII) upon diaphragmatic (a) and visceral (b) surfaces.

forward, reaching the portal fissure next to the fissure for ligamentum venosum.

On the underside of the liver there are several impressions formed by adjoining organs. In the left region there is a g a s t r i c i m p r e s s i o n. On the posterior part of the left lobe is the o e s o p h a g e a l i m p r e s-s i o n. On the quadrate lobe, near the fossafor gallbladder is the duodenal impression. To its right, on the right lobe, there is an impression formed by the right kidney. To the left of the renal impression, near the groove for vena cava, is the suprarenal impression. Along the inferior margin of the visceral surface is the c o l i c i m p r e s s i o n.

The liver is made up of five s e c t o r s and eight s e g m e n t s (Fig. 140). A sector is a fragment, supplied with blood by second level branches of the portal vein and hepatic artery. Each such fragment contains a sector bile duct. A segment is a part of the liver, which receives blood supply from a third level branch of the portal vein and contains a segmental bile duct. Segments are numbered on the visceral surface of the liver beginning at the

Fig. 141. Construction of hepatic lamina (acc. to V.G.Eliseev).

1 — hepatocyte; 2 — hepatic lamina; 3 — haemocapillare (sinusoid vessel); 4 — perisinusoidal space of Disse; 5 — central vein; 6 — perisinusoidal lypocyte; 7 — bile capillare; 8 — reticulocyte; 9 — endotheliocyte; 10 — perilobular bile canaliculus; 11 — perilobular artery; 12 — perilobular vein.

fissure of the inferior vena cava, in the clockwise direction. The right lobe contains segments 1–4, and the left lobe — segments 5–8.

The fibrous capsule of the liver gives off thin connective tissue septa into its parenchyma, dividing it into lobules. A lobule is the functional unit of the liver. It is shaped like a prism with a diameter of 1.0–1.5 mm (Fig. 141, 142). The total number of lobules is approximately 500 thousand. Each lobule consists of cords of hepatocytes, which begin in the center of the lobule and spread out to its periphery. Each cord consists of two rows of hepatocytes. Situated between two rows of cells of a cord are initial parts of the biliary ducts. Between the cords are blood capillaries (sinusoids), which collect into the central vein of the lobule. The space between
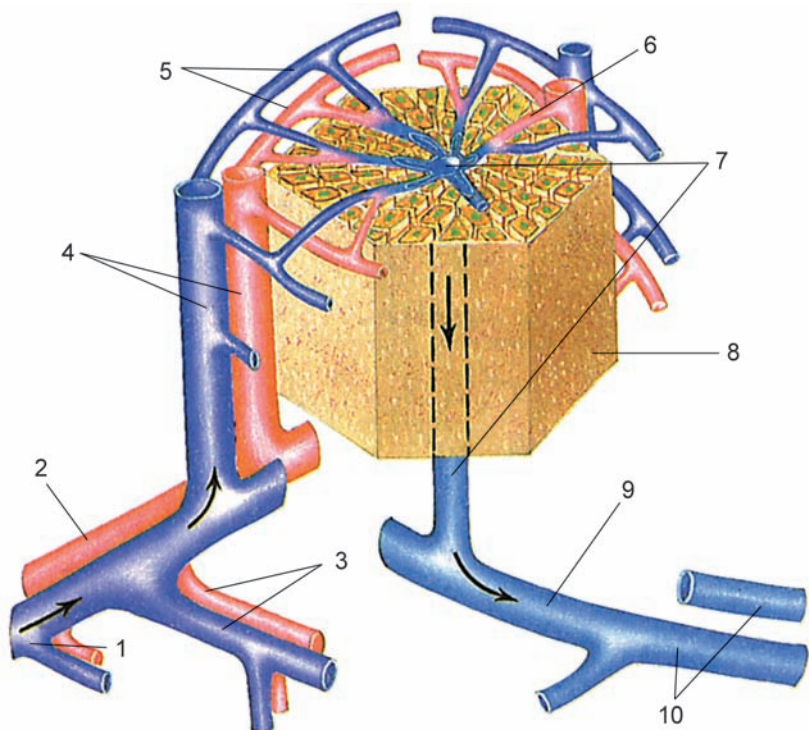
Fig. 142. Blood supply of liver. (acc to V.G.Eliseev and others).

1 — portal vein; 2 — hepatic artery proper; 3 — segmental vein and artery; 4 — interlobular artery and vein; 5 — perilobular veins and arteries; 6 — intralobular haemocapillaries (sinusoid vessels); 7 — central vein; 8 — hepatic lobule («classic»); 9 — collective vein; 10 — hepatic veins.

the walls of sinusoid capillaries and hepatocytes is called p e r i s i n u s o-
i d a l (Disse's) s p a c e. Between lobules there is a small amount of con-
nective tissue, which contains hepatic triad complexes that include an in-
terlobular bile duct and branches of the portal vein and hepatic artery.
Such a construction allows hepatocytes to simultaneously excrete bile into
bile ducts, and glucose, lipids, urea, vitamins and other substances—into
to blood vessels.

H e p a t o c y t e s are polygonal cells with a diameter of 20–25 mm.
Most hepatocytes have only one nucleus, but some have two or several.
Their cytoplasm may be coarse or fine-grained, depending on the compo-
sition of its inclusions (lipids, pigments). Hepatocytes contain a lot of mi-
tochondria, a well-developed endoplasmic reticulum and Golgi complex,
and a large amount of ribosomes, lysosomes and micro-vesicles, contain-

ing lipid metabolism enzymes. The cytoplasm contains grains of glycogen. The cell membrane of hepatocytes forms numerous microvilli, directed into the perisinusoidal space.

Biliary system

The liver is a compound tubular gland with a branching system of bile ducts. Bile ductules, or canaliculi, begin in the hepatic acini, where the width of their lumens is 0.5–1.0 mm. These canaliculi do not have walls, but are dilated zones of intercellular fissures between hepatocytes. Bile ductules have short blind branches, which extend between neighboring hepatocytes. Bile ductules begin blindly near the central vein and pass to the peripheries of lobules, where they collect into short bile ducts called c h o l a n g i o l e s (intermediate canals of Hering), which open into i n t e r l o b u l a r b i l e d u c t s. The interlobular ducts connect with each other, gradually increasing in diameter, and form the r i g h t and l e f t h e p a t i c d u c t s. In the porta hepatis these two ducts are connected with each other and form the c o m m o n h e p a t i c d u c t, which is 4–6 cm long. Between the sheets of the hepatoduodenal ligament the common hepatic duct is connected with the c y s t i c d u c t (from the gallbladder), forming the common bile duct.

The bile duct (dúctus cholédochus) is situated between the sheets of hepatoduodenal ligament, in front of the portal vein and to the right of the hepatic artery. Further the bile duct passes behind the superior part of the duodenum, and then between its descending part and the head of the pancreas. Inside the wall of the duodenum it connects with the p a n c r e a t i c d u c t, forming the h e p a t o p a n c r e a t i c a m p u l l a. This ampulla opens into the duodenum through the apex of the major duodenal papilla. In the walls of the hepatopancreatic ampulla there is a s p h i n c t e r (sphincter of Oddi), formed by a thickening of circular muscle fascicles. The distribution of muscle fascicles of the sphincter is uneven. Their thickness near the base of the major papilla reaches 75 mm, and closer to the top of the papilla — 40 mm. The width of the sphincter is 15–20 mm. In periods between digestion the sphincter of Oddi stays closed and bile accumulates in the gallbladder. During digestion the sphincter opens and bile enters the duodenum.

The walls of the bile duct contain another sphincter, which is situated just before its junction with the main pancreatic duct. By closing this sphincter prevents bile from entering the hepatopancreatic ampulla and the duodenum.

The walls of interlobular ducts are formed by simple cuboidal epithelium. The walls of the hepatic, cystic and bile ducts are formed by three

layers. Their m u c o s a is lined with simple columnar epithelium, which contains goblet cells. The lamina propria of the mucosa is well developed and contains a large amount of longitudinal and circular elastic fibers and some multicellular mucous glands. The s u b m u c o s a is weakly developed. The m u s c u l a r i s is thin, and consists primarily of spiral muscle fascicles, the spaces between which are filled with connective tissue.

I n n e r v a t i o n o f t h e l i v e r: branches of vagus nerves and hepatic (sympathetic) plexus.

Blood vessels of the liver: The porta hepatica contains the hepatic artery and portal vein. The artery carries arterial blood. The hepatic portal vein brings venous blood from the stomach, pancreas, intestines, and spleen. Inside the liver the portal vein and hepatic artery branch out into interlobular arteries and veins, which stay together with interlobular bile ducts within the hepatic triads. The interlobular veins and arteries branch out into the sinusoids, which collect into the central vein. Central veins of the liver lobules connect with each other, forming sublobular (collecting) veins. These veins merge with each other, increasing in diameter, and, finally, form 2–3 hepatic veins. The hepatic veins exit the liver through the groove of the inferior vena cava, where they join the latter.

L y m p h o u t f l o w: hepatic, celiac, right lumbar, superior diaphragmatic and parasternal lymph nodes.

Gallbladder

The gallbladder (vésica féllea) is a pear-shaped organ, in which bile is accumulated and concentrated. It is situated in the right subcostal region. Its upper surface adjoins the fossa for gallbladder on the visceral surface of the liver. Its free lower surface is turned into the abdominal cavity and is covered by peritoneum. It adjoins the front wall of the superior part of duodenum and the right colic flexure. The length of the gallbladder is 8–12 cm, and the width is 4–5cm.. Its volume is approximately 40 cm^3. The gallbladder has a broadened f u n d u s, a b o d y and a n e c k. Its f u n d u s slightly protrudes from underneath the inferior margin of the liver, next to the junction of the eighth and ninth costal cartilages. It continues into the gallbladder body, which narrows and becomes the neck. The neck forms the beginning of the cystic duct. The n e c k and cystic duct, which are directed toward the porta hepatis, lie within the hepatoduodenal ligament. At the transition between its body and neck the gallbladder forms a flexure, such that the neck and the body are situated at an angle to each other.

The wall of the gallbladder consists of the m u c o s a, s u b m u c o s a, m u s c u l a r c o a t and s e r o s a. The mucosa is thin, and forms numer-

ous tiny folds. In the region of the neck these rugae have a spiral orientation. The gallbladder mucosa is lined with simple columnar epithelium. The well-developed lamina propria contains solitary and small groups of lymphocytes, mucous glands, blood vessels and nerves. The submucosa of the gallbladder is thin. The muscularis layer is formed by a single layer of smooth myocytes, which form longitudinal and spiral fascicles. The muscularis is less developed in the fundus, and is thicker in the neck, where it continues into the muscle layer of the cystic duct. To the outside of the muscularis is the subserosa and serosa, which is formed by the peritoneum. The peritoneum covers the gallbladder from the sides and bottom, while its hepatic surface is covered by adventitia.

I n n e r v a t i o n of the gallbladder: branches of the vagus nerves and the hepatic (sympathetic) plexus.

B l o o d   s u p p l y: cystic artery (from hepatic artery).

Ve n o u s   o u t f l o w: cystic vein (into portal vein).

L y m p h a t i c   r e t u r n: hepatic and cystic lymphatic nodes.

Questions for revision and examination

1. Where on the front abdominal wall do projections of the superior and inferior liver margins meet in an adult person?
2. What organs adjoin the visceral surface of the liver?
3. What is a liver lobule? How is it structured?
4. Describe the sizes and volume of the gallbladder.
5. Describe the structure and topography of the common bile duct.

PANCREAS

The pancreas (páncreas) – is an elongated pinkish-gray organ, which lies retroperitoneally (Fig.143). The pancreas is a large alimentary gland, which produces mixed secretion. It has an exocrine compartment, consisting of typical secretory sections and excretory duct system, and an endocrine part. As an exocrine gland it produces 500–700 ml of pancreatic juice per day. This juice contains proteolytic, amylolytic and lipolytic enzymes (trypsinogen, chymotrypsinogen, prolipase, amylase, etc.). The endocrine part of the gland consists of numerous groups of cells (pancreatic islets), which produce hormones that regulate metabolism of carbohydrates and lipids (insulin, glucagon, etc).

The pancreas is 14–18 cm long, 6–9 cm wide and 2–3 cm thick. It weights 85–95 g. The gland is covered by a thin connective tissue capsule. It extends from the level of the T12 vertebra obliquely downward and to the right, to the level of L1-L3 vertebrae. The pancreas consists of a head, body and tail.
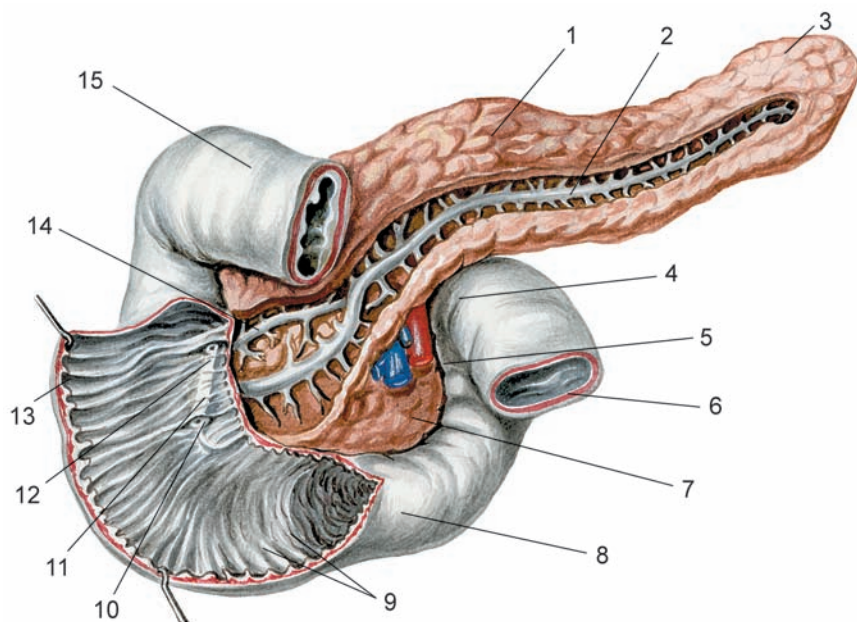
Fig. 143. Pancreas. Anterior aspect. Duct is opened. Anterior wall of pancreas
is cut and pulled aside.

1 — body of pancreas; 2 — pancreatic duct; 3 — tail of pancreas; 4 — duodeno-jejunal flexure;
5 — ascending part of duodenum; 6 — jejunum; 7 — uncinate process; 8 — horizontal part of
duodenum; 9 — circular folds; 10 — major duodenal papilla; 11 — longitudinal fold of duodenum;
12 — minor duodenal papilla; 13 — descending part of duodenum; 14 — accesory pancreatic
duct; 15 — superior part of duodenum.

The h e a d o f t h e p a n c r e a s (Fig.144) is slightly flattened and
resembles the head of a hammer. The boundary between the head and the
body is marked by the p a n c r e a t i c n o t c h, located on its lower edge.
The head is turned toward the medial wall of the duodenum. In the fissure
between the head and duodenal wall passes the superior mesenteric vein
and, usually, the anastomosis between the superior and inferior pancreat-
icoduodenal arteries. In the back the head of the pancreas lies against the
inferior vena cava, right renal vein and the beginning part of the portal
vein. In front of the head lies the transverse colon.

The b o d y o f t h e p a n c r e a s is trihedral in shape. It has three
surfaces. The a n t e r o s u p e r i o r s u r f a c e is covered by parietal peri-
toneum, which forms the posterior wall of the omental bursa. On this
surface there is an o m e n t a l e m i n e n c e. The p o s t e r i o r s u r f a c e
of the body adjoins the vertebral column, inferior vena cava, aorta, splen-
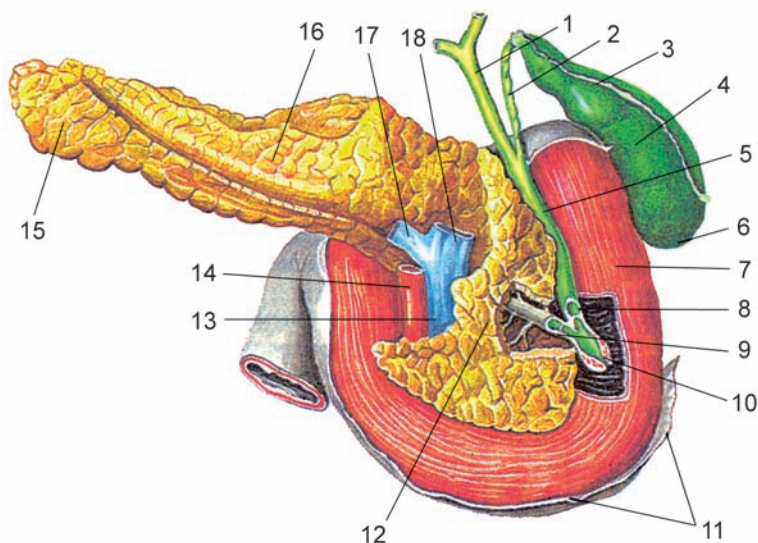
Fig. 144. Pancreas; gallbladder; bile ducts and duodenum. Posterior aspect.

1 — commone hepatic duct; 2 — cystic duct; 3 — neck of gallbladder; 4 — body of gallbladder; 5 — bile duct; 6 — fundus of gallbladder; 7 — duodenum; 8 — sphincter of common bile duct; 9 — pancreatic duct and its sphincter; 10 — sphincter of hepato-pancreatic ampulle (Oddi's sphincter); 11 — peritoneum; 12 — head of pancreas; 13 — superior mesenteric vein; 14 — superior mesenteric artery; 15 — tail of pancreas; 16 — body of pancreas; 17 — splenic vein; 18 — hepatic portal vein.

ic arteries and veins, and the celiac plexus. The a n t e r o-i n f e r i o r s u r-f a c e is narrow and is partially covered by peritoneum. The inferior and superior anterior surfaces are divided by the anterior border of the gland. At the level of the anterior border lies the mesentery root of the transverse colon.

The t a i l o f t h e p a n c r e a s extends to the left, where it lies against the visceral surface of the spleen, somewhat below its hilum. Behind the tail lies the left adrenal gland and the upper part of the left kidney.

The parenchyma of the pancreas is divided into the lobules by connective tissue trabeculae, which begin from the capsule of the gland. The lobules contain the secretory compartments, which resemble hollow pouches 100–500 mm in size. Each excretory compartment consists of 8–14 pyramid-shaped cells called exocrine pancreatocytes (acinocytes) (Fig. 145). The excretory cells are situated on a basement membrane. From the cavities of excretory compartments extend the intercalary excretory ducts, which are lined with simple squamous epithelium. Intercalary ducts flow into intralobular ducts, which are lined with simple cuboidal epithelium. The interlobular ducts pass through interlobular connective trabeculae. The
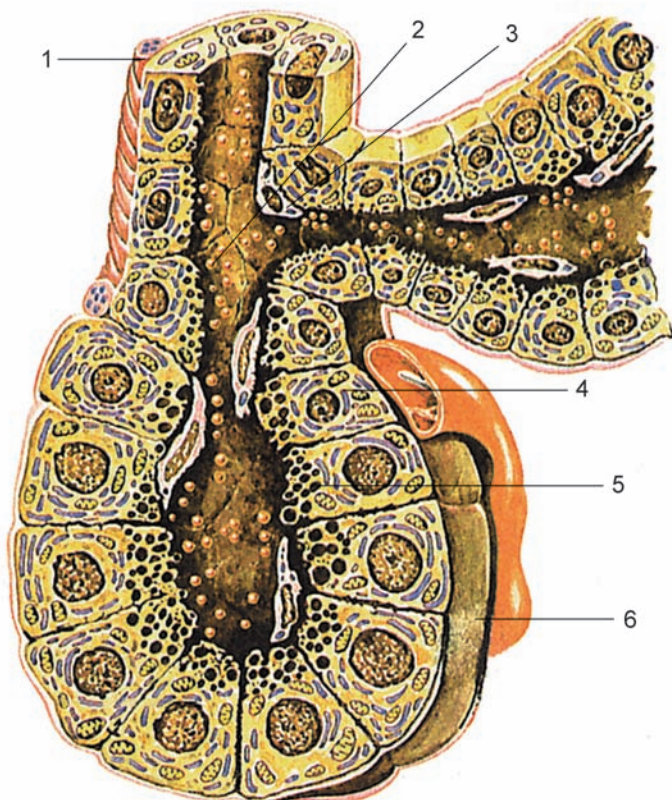
Fig. 145. Construction of the pancreatic acinus (acc. to V. G. Eliseev).

1 — nerve fiber; 2 — intercalary duct; 3 — centroacinal cells; 4 — acinal cells; 5 — secretory granules of apical parts of cells; 6 — haemocapillaries.

walls of the interlobular ducts are formed by simple columnar epithelium and its lamina propria. Interlobular ducts flow into the main pancreatic gland.

The p a n c r e a t i c   d u c t (d ú c t u s   p a n c r e á t i s), or duct of Wirsung, passes inside the gland, closer to its posterior surface. This duct begins in the tail of the gland and passes through the body and the head, receiving the smaller interlobular ducts. It opens into the descending part of the duodenum on the major duodenal papilla, after uniting with the common bile duct. In the end of the pancreatic duct its wall contains a sphincter, formed by a thickening of circular smooth muscular fascicles.

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Often the pancreatic and bile ducts have separate openings in the duodenal wall, in which case the major papilla may or may not be absent.

Formed in the head of the pancreas is an accessory pancreatic duct (the duct of Santorini), which opens into the duodenum on top of the minor duodenal papilla. Sometimes there is an anastomosis between the main and accessory pancreatic ducts.

The walls of the main and accessory ducts are lined with columnar epithelium. The epithelium of the pancreatic excretory duct system contains goblet cells, which produce mucus, and endocrinocytes. The endocrine cells of the ducts secrete pancreozinin and cholecystokinin. The lamina propria of interlobular, accessory and main pancreatic ducts contains numerous mucous glands.

The e n d o c r i n e p a r t o f t h e p a n c r e a t i c g l a n d is formed with p a n c r e a t i c i s l e t s (islets of Langerhans), which are, consist of groups of endocrinocytes. They are located primarily in the tail of the pancreas. These islets be round, oval or, sometimes, strip or stellar shape. Their total quantity ranges between 0.2 and 1.8 million. Their diameter varies from 100 to 300 mm, and weight — from 0.7 to 2.6 g. There are several different types of endocrinocytes, which form these islets. Their structure is described in the «Endocrine system» section.

I n n e r v a t i o n of the pancreas: branches of vagus nerves (mainly right vagus nerve), sympathetic nerves from the celiac plexus.

B l o o d s u p p l y: anterior and posterior superior pancreaticoduodenal arteries (from gastroduodenal artery), inferior pancreaticoduodenal artery (from the superior mesenteric artery).

V e n o u s o u t f l o w: pancreatic veins (into superior mesenteric, splenic and other veins of the portal vein system).

L y m p h o u t f l o w: pancreatic, pancreaticoduodenal, pyloric and lumbar lymph nodes.

Questions for revision and examination

1. What organs adjoin the posterior surface of the pancreas? What organs adjoin its anterior surface?
2. Describe the structure of exocrine secretory compartments of the pancreas and its excretory ducts.
3. How many excretory ducts does the pancreas have?

PERITONEUM

The peritoneum (peritóneum) is a thin serous membrane, which lines the abdominal cavity, covering many of its organs. It is formed by several alternating layers of collagen and elastic fibers, lined by squamous me-

sothelial cells. Its surface area is approximately 1.7 m². The peritoneum carries out integumentary and protective functions. It contains immune structures (lymphoid nodules) and adipose tissue (fat storage). Duplications of peritoneum form ligaments, which fixate internal organs, preventing their excessive movement. The peritoneum, which lines the walls of the abdomen, is called p a r i e t a l p e r i t o n e u m, and that, which covers its organs is called v i s c e r a l p e r i t o n e u m (Fig.146). When passing between the organs this membrane forms ligaments (folds). The sheets of peritoneum, which pass onto the organs from the posterior abdominal wall, form the mesentery of these organs. Between the sheets of the mesentery there are blood vessels and nerves. The beginning part of the mesentery, located on the posterior abdominal wall, is called the root of the mesentery. The space within the abdominal cavity, which is confined by peritoneum, is called t h e p e r i t o n e a l c a v i t y (c á v u m p e r i t o n e i). At the bottom the peritoneal cavity descends into the pelvis. In men this cavity is completely closed. In women it communicates with the external environment through the abdominal openings of the uterine tubes, the uterus and vagina. The peritoneal cavity contains a small amount of serous fluid,
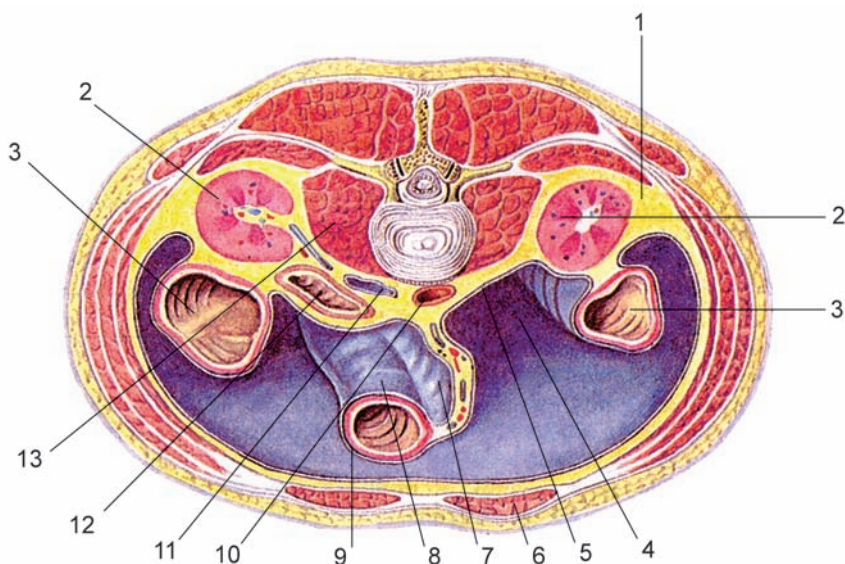
Fig. 146. Abdominal cavity. Horizontal cut of human body between LII and LIII (acc. to R.D.Sinelnikov).

1 — retroperitoneal space; 2 — kidney; 3 — colon; 4 — peritoneal space; 5 — parietal peritoneum; 6 — rectus abdominis muscle; 7 — mesentery; 8 — small intestine; 9 — visceral peritoneum; 10 — aorta; 11 — inferior vena cava; 12 — duodenum; 13 — psoas major muscle.
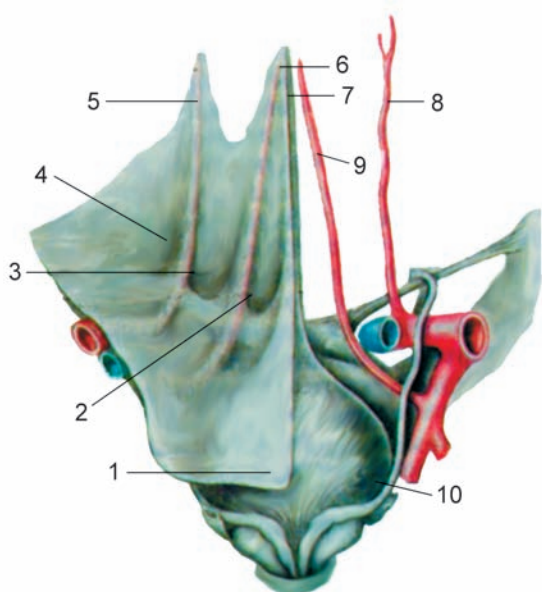
Fig. 147. Posterior surface of anterior abdominal wall.

1 — peritoneum; 2 — suprovesical fossa; 3 — medial inguinal fossa; 4 — lateral inguinal fossa; 5 — lateral umbilical fold; 6 — medial umbilical fold; 7 — middle umbilical fold; 8 — inferior epigastric artery; 9 — umbilical artery; 10 — urinary bladder.

which moistens the peritoneum, enabling the organs to glide freely against each other.

The relationship of the peritoneum with different organs of the abdominal cavity varies. For example, the kidneys, adrenal glands, ureters, most of the duodenum, the pancreas, abdominal aorta and the inferior vena cava lie retroperitoneally. They are covered by peritoneum only from the front. Organs, which are covered by peritoneum from three sides (ascending and descending colons, middle part of the rectum) are called mesoperitoneal. Organs, which are covered by peritoneum on all sides, are called intraperitoneal. This last group includes the stomach, jejunum and ileum, transverse and sigmoid colons, upper part of the rectum, spleen and liver.

The peritoneum of the anterior abdominal wall at the top passes onto the diaphragm; at the sides — onto the lateral abdominal walls; and at the bottom — the inferior wall of the pelvic cavity. On the front abdominal wall there are 5 well-defined folds (Fig. 147). The m e d i a n u m b i l i c a l f o l d passes from the apex of the bladder to the umbilicus, and contains the obliterated urinary duct. To its sides are the paired m e d i a l u m b i l i c a l f o l d s, which contain the obliterated umbilical arteries. The l a t e r a l u m - b i l i c a l f o l d s contain the inferior epigastric arteries. Between these folds are fossae, which are the weak points of the abdominal wall, and are a common site of inguinal hernias. Above the bladder, at the sides of the median umbilical fold, are the right and left s u p r a v e s i c a l f o s s a e (usually hernia do not form here). Between the medial and lateral umbilical folds are the m e d i a l i n g u i n a l f o s s a e, which correspond to the super-

ficial inguinal rings. To the outside of the lateral umbilical folds are the lateral inguinal fossae, which correspond to the deep inguinal rings.

The parietal peritoneum above the umbilicus forms the f a l c i f o r m l i g a m e n t of the liver. This ligament stretches between the anterior abdominal wall and diaphragm and the diaphragmatic surface of the liver, where its sheets continue into visceral peritoneum (Fig. 148). Inside the free lower (anterior) margin of this ligament passes the r o u n d l i g a - m e n t (ligamentum téres), which is an obliterated umbilical vein. In the back, the sheets of the falciform ligament pass into the coronal ligament of the liver. The c o r o n a r y l i g a m e n t is stretched in the frontal plane, and is formed by the transition between visceral peritoneum of the liver and parietal peritoneum of the posterior abdominal wall. At the sides the coronal ligament spreads out, forming the r i g h t a n d l e f t t r i a n g u l a r l i g a m e n t s. The visceral peritoneum of the inferior (visceral) surface of
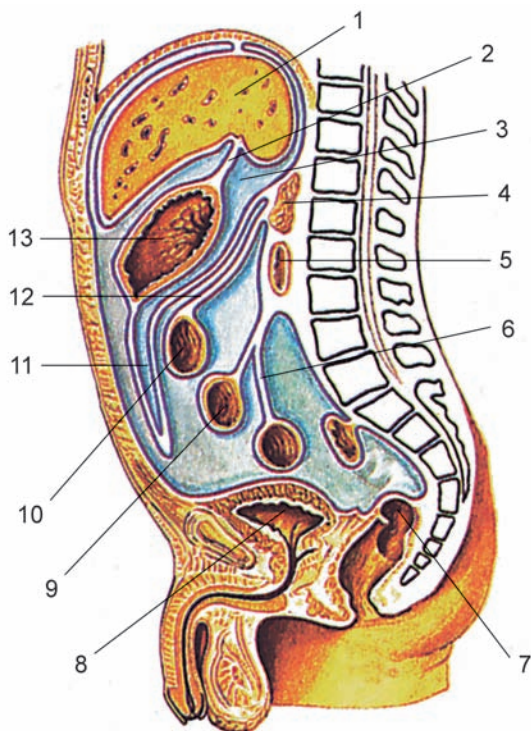
Fig. 148. Position of intestines and peritoneum. Median sagittal section of human body.
1 — liver; 2 — hepatogastric ligament; 3 — omental bursa; 4 — pancreas; 5 — duodenum; 6 — mesentery; 7 — rectum; 8 — urinary bladder; 9 — small intesine; 10 — transverse colon; 11 — cavity of greater omentum; 12 — transverse mesocolon; 13 — stomach.

theliver covers the bottom surface of the gallbladder. From the visceral surface of the liver two peritoneal sheets extend to the lesser curvature of the stomach and the beginning part of the duodenum, forming the hepatogastric and hepatoduodenal ligaments. Inside the hepatoduodenal ligament lie, from left to right, the common bile duct, the portal vein and the hepatic artery, nerves and lymph vessels and nodes. The h e p a t o g a s t r i c and h e p a t o d u o d e n a l l i g a m e n t s together form the minor omentum (omentum minus).

The sheets of the visceral peritoneum of the anterior and posterior walls of the stomach continue from its greater curvature downwards, to the upper inlet into the lesser pelvis. At this level (or a little higher) the two sheets turn back and ascend to the posterior abdominal wall (at the level of the pancreas). These four sheets of visceral peritoneum form the g r e a t e r o m e n t u m (o m é n t u m m á j u s). At the level of the transverse colon all four sheets accrete with the taenia coli, which is situated on its anterior surface. From there the posterior two sheets of peritoneum pass over the transverse mesocolon onto the posterior abdominal wall. One of these sheets continues onto the anterior surface of the pancreas, and the other continues downwards, becoming the upper sheet of the t r a n s v e r s e m e s o c o l o n. The part of the greater omentum, which stretches between the greater curvature of the stomach and the transverse colon, is called the g a s t r o c o l i c l i g a m e n t. The greater omentum covers in the front the jejunum and part of the ileum. Two sheets of peritoneum, which stretch from the greater curvature of the stomach to the hilum of the spleen, form the g a s t r o s p l e n i c l i g a m e n t. There is also a g a s t r o d i a p h r a g m a t i c and d i a p h r a g m a t i c o s p l e n i c l i g a m e n t s.

The p e r i t o n e a l c a v i t y is divided into upper and lower levels, the border between which is formed by the transverse colon and its mesentery. The upper level is confined by the diaphragm, lateral abdominal walls and the transverse colon with its mesentery. The transverse mesocolon is attached to the posterior abdominal wall at the level of the tenth ribs. The upper level of the peritoneal cavity contains the stomach, liver and spleen. Retroperitoneally at this level lie the superior part of the duodenum and the pancreas. The upper level has three separate compartments, called the hepatic, pregastric and omental bursae. The h e p a t i c b u r s a is situated in the right subcostal region and contains the right lobe of the liver. It has a suprahepatic fissure (i n f r a d i a p h r a g m a t i c s p a c e) and an infrahepatic fissure (i n f r a h e p a t i c s p a c e). It is separated from the other bursae by the falciform and coronal ligaments. The hepatic bursa communicates with the pregastric bursa and the right lateral canal.

The p r e g a s t r i c   b u r s a is situated in the frontal plane in front of the stomach and lesser omentum, between the falciform ligament on the right and the diaphramaticocolic ligament on the left. Its superior wall is formed by the diaphragm, and the inferior wall — by the transverse colon. In front it is bounded by the anterior abdominal wall. On the right this bursa communicates with the infrahepatic fissure and the omental bursa, and on the left — with the left lateral canal.

The o m e n t a l   b u r s a (b ú r s a   o m e n t á l i s) is situated behind the stomach, lesser omentum and gastrocolic ligament. At the top the omental bursa is bordered by the caudate liver lobe; at the bottom—by the posterior lamina of the greater omentum, which accretes with the mesentery of the transverse colon. In the back the omental bursa is bordered by parietal peritoneum, which covers the aorta, inferior vena cava, upper pole of the left kidney, left adrenal gland and pancreas. The cavity of the omental bursa has the shape of a fissure, situated in the frontal plane, and contains three recesses. The s u p e r i o r omental r e c e s s is situated between the lumbar part of the diaphragm and the caudate liver lobe. The s p l e n i c r e c e s s is situated between the gastrosplenic ligament, the diaphragmaticosplenic ligament and the hilum of the spleen. The i n f e r i o r omental r e c e s s is bordered by the gastrocolic ligament at the top and front, and, at the bottom, by the posterior lamina of the greater omentum (accreted with the transverse colon mesentery). The omental bursa communicates with the hepatic bursa (infrahepatic fissure) through the e p i p l o i c (Winslow's) f o r a m e n. This foramen is 3–4 cm wide, and is limited in the front by the hepaticoduodenal ligament, and in the back — by parietal peritoneum, which covers the inferior vena cava. At the top the epiploic foramen is limited by the caudate lobe of the liver, and at the bottom — by the superior part of the duodenum.

The lower level of the peritoneal cavity is situated beneath the transverse colon and its m e s e n t e r y. At the bottom it is limited by the peritoneum, which lines the floor of the pelvic cavity. This level contains two paracolic grooves (lateral canals) and two mesenteric sinuses (Fig.149). The r i g h t   p a r a c o l i c   g r o o v e (r i g h t   l a t e r a l   c a n a l) is situated between the right abdominal wall and the ascending colon. The l e f t p a r a c o l i c   g r o o v e (l e f t   l a t e r a l   c a n a l) is bordered by the left abdominal wall and the descending colon. The mesentery of the small intestine divides the two mesenteric sinuses. The r o o t   o f   t h e   m e - s e n t e r y extends on the posterior abdominal wall between the levels of the duodenojejunal transition on the left and the sacroiliac joint on the right. The r i g h t   m e s e n t e r i c   s i n u s is limited on the right by the ascending colon; at the top by the root of the transverse mesocolon; and
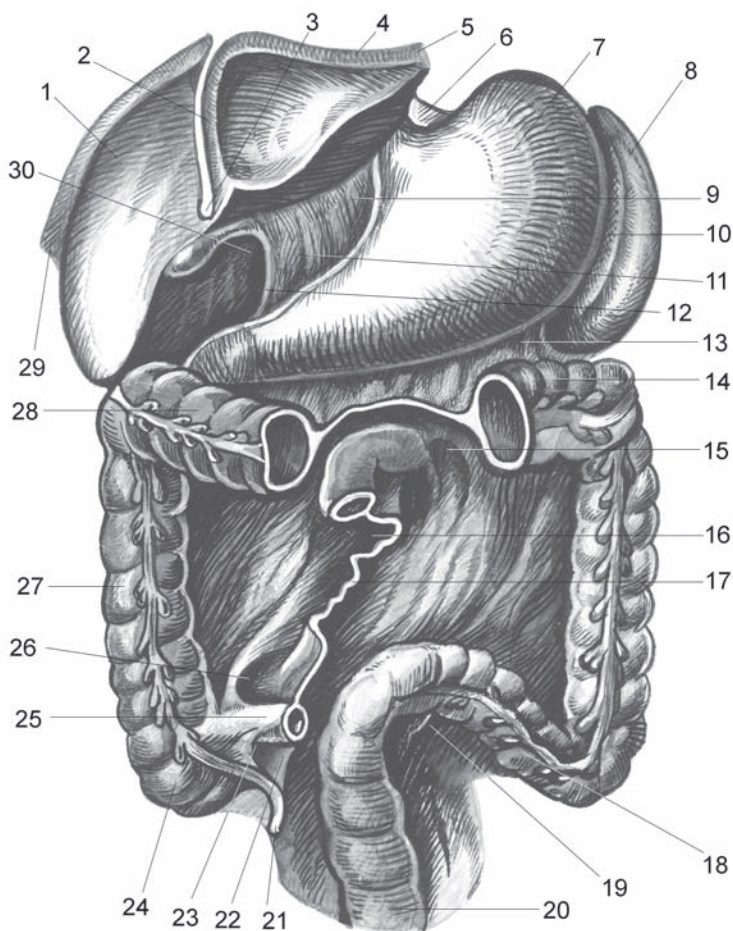
Fig. 149. Mesenteric sinuses; ligaments of peritoneum within abdominal cavity. Part of transverse colon is removed.

1 — liver; 2 — falciform ligament; 3 — round ligament of the liver; 4 — coronal ligament; 5 — left triangular ligament; 6 — gastrophrenic ligament; 7 — stomach; 8 — spleen; 9 — hepatogastric ligament; 10 — gastrolienal ligament; 11 — hepatoduodenal ligament; 12 — anterior wall of omental foramen; 13 — mesocolon; 14 — transverse colon; 15 — superior duodenal fossa; 16 — descending colon; 17 — root of mesentery; 18 — sigmoid colon; 19 — intersigmoid recess; 20 — rectum; 21 — appendix; 22 — mesoappendix; 23 — inferior ileocaecal recess; 24 — caecum; 25 — jejunum; 26 — superior ileocaecal recess; 27 — ascending colon; 28 — transverse colon; 29 — right triangular ligament; 30 — omental foramen.

on the left by the root of the jejunal and ileal mesenteries. Within these boundaries, retroperitoneally lies the bottom of the descending part and the horizontal part of the duodenum, lower part of the head of pancreas, part of the inferior vena cava, right ureter, vessels, nerves and lymph nodes.
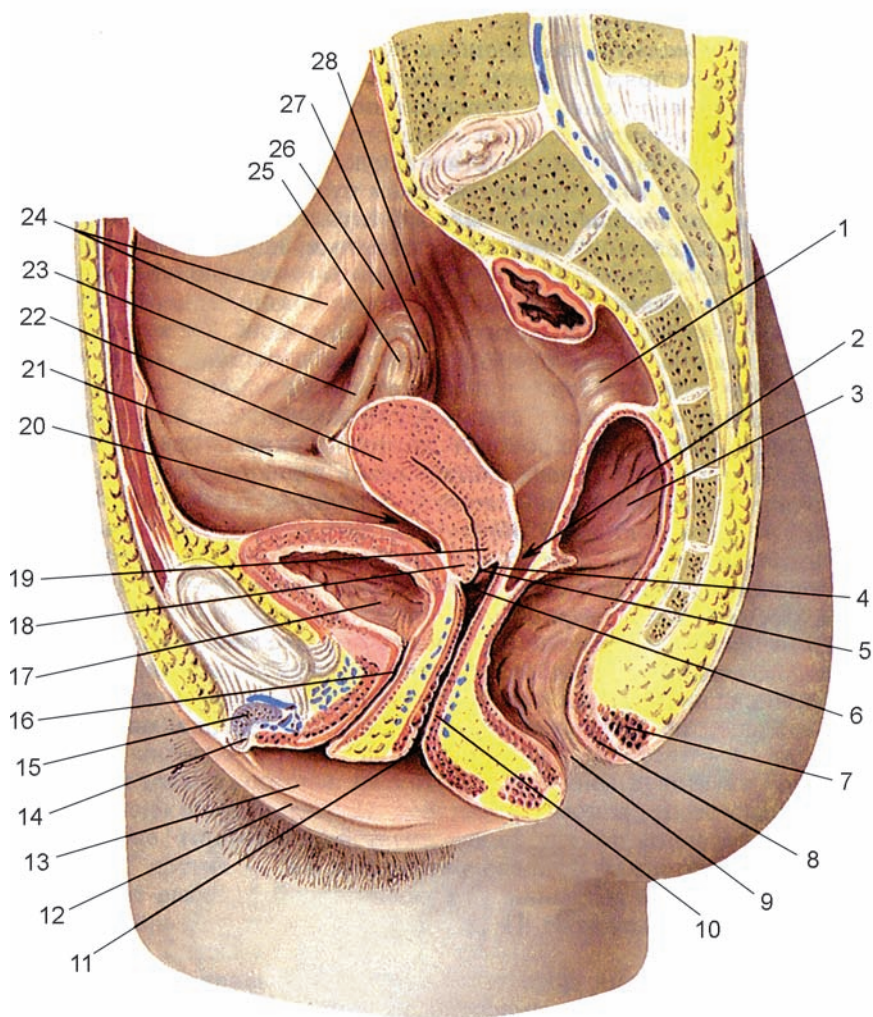
Fig. 150. Peritoneum of female pelvic cavity.

1 — rectum; 2 — recto-uterine pouch; 3 — rectal ampulla; 4 — posterior part of vaginal fornix; 5 — external orifice of uterus; 6 — anterior part of vaginal fornix; 7 — external anal sphincter; 8 — internal anal sphincter; 9 — anus; 10 — vagina; 11 — vaginal orifice; 12 — labium majus; 13 — labium minus; 14 — head of clitoridis; 15 — body of clitoridis; 16 — urethra; 17 — urinary bladder; 18 — anterior lip of external os of uterus; 19 — posterior lip of external os of uterus; 20 — vesico-uterine pouch; 21 — round ligament of uterus; 22 — uterus; 23 — uterine tube; 24 — external iliac artery and vein; 25 — ovary; 26 — suspensory ligament of ovary; 27 — ovarian fimbria; 28 — ureter.

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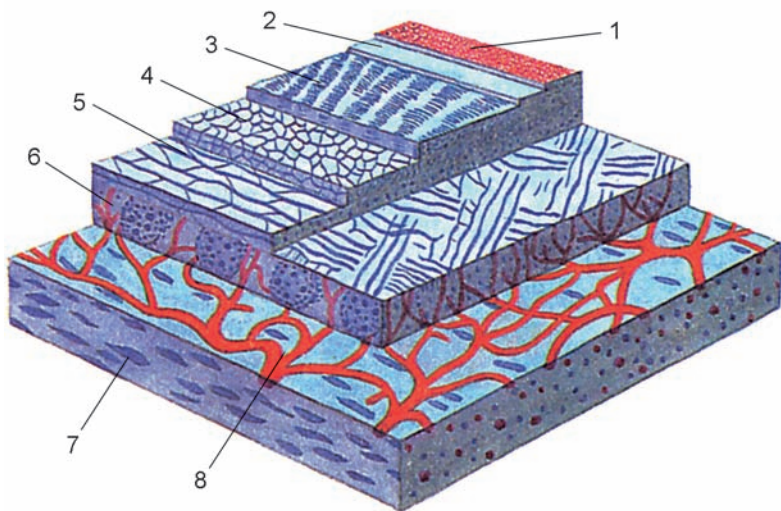
Fig 151. Construction of peritoneum.

1–5 – layers of peritoneum (without vessels); 6 — deep cribrosal collagen-elastic layer (with blood vessels); 7 — smooth muscles; 8 — serosal-muscular network of blood vessels.

The right mesenteric sinus contains some loops of the ileum. The l e f t m e s e n t e r i c s i n u s is limited by the descending colon on the left and the root of the small intestine mesentery on the right. At the bottom it communicates with the pelvic cavity. Retroperitoneally, within the boundaries of this sinus, lies the ascending part of the duodenum, lower half of the left kidney, end part of the abdominal aorta, left ureter, vessels, nerves and lymph nodes. This sinus primarily contains loops of the jejunum.

The parietal peritoneum, which forms the posterior wall of the peritoneal cavity, forms recesses (fossae), which may become sites of retroperitoneal herniae. The s u p e r i o r and i n f e r i o r d u o d e n o j e j u n a l r e c e s s e s are situated above and below the duodenojejunal flexure. The s u p e r i o r and i n f e r i o r i l e o c a e c a l r e c e s s e s are situated above and below the ileocecal valve. Beneath the cupola of the cecum is the r e t r o c e c a l r e c e s s. To the left of the sigmoid mesocolon lies the sigmoid recess.

In the cavity of the lesser pelvis the peritoneum forms recesses between its organs. In men the peritoneum covers the anterior surface of the rectum, passes onto the posterior and superior surfaces of the urinary bladder, and then continues into parietal peritoneum of the anterior abdominal wall. Between the bladder and rectum there is a r e c t o v e s i c a l p o u c h. At the sides it is bordered by the r e c t o v e s i c a l f o l d s, which stretch

between the rectum and the bladder. In women the peritoneum passes from the rectum onto the back of the vagina, passes over the uterus and onto the urinary bladder in the front (Fig. 150). Between the uterus and the bladder is the v e s i c o u t e r a l p o u c h. Between the uterus and rectum is the deep r e c t o u t e r i n (Douglas's) p o u c h. At the sides this recess if limited by the r e c t o u t e r a l f o l d s.

The peritoneum consists of mesothelium, collagen and elastic networks, as well as smooth muscle cells (Fig. 151).

Questions for revision and examination

1. Name the retroperitoneal, mesoperitoneal and intraperitoneal organs of the abdominal cavity.
2. Name the folds and fossae on the posterior surface of the anterior abdominal wall, below the umbilicus.
3. Name the walls of the omental bursa and the location of its recesses. Name the walls of the hepatic and pregastric bursae.
4. What structures border the paracolic grooves and mesenteric sinuses?
5. What recesses (fossae) are found on the posterior abdominal wall and are possible sites of hernia formation?

DEVELOPMENT OF THE DIGESTIVE SYSTEM

Beginning on day 20 of the intrauterine development the intestinal ectoderm of the embryo rolls into a tube, forming the primitive gut. The primitive gut is situated in front of the chorda, and is closed in the front and the back. The ectoderm forms into the epithelium and glands of the digestive tract (excluding the mouth and anal regions). The other layers of the digestive tube develop from the splanchnopleura, which is the medial unsegmented lamina of the mesoderm, which adjoins the primitive gut.

During week 3 of embryogenesis ectodermal depressions appear in the cranial (stomodeum) and caudal (proctodeum) ends of the embryo. The stomodeum protrudes into the cranial end of the primitive gut. The membrane between the stomodeum and the gut (oral membrane) erupts during the fourth week. The cloacal membrane, which separates the proctodeum from the cavity of the primitive gut, erupts somewhat later.

During the fourth week the ventral wall of the primitive gut protrudes forward, later to form the trachea, bronchi and lungs). This protrusion marks the border between the caudal (pharyngeal) and the truncal guts. The truncal gut is divided into an anterior, middle and posterior guts. The ectodermal lining of the stomodeum develops into the epithelium of the oral cavity. The caudal gut develops into epithelium of the pharynx. The anterior gut forms the epithelium of the oesophagus and stomach; the middle gut — the cecum, ascending and transverse colons and epithelium of

the liver and pancreas. The posterior gut develops into epithelium of the descending and sigmoid colons and rectum. The peritoneum is formed by the somatopleura and visceropleura.

Development of walls of the oral cavity, bones of the facial skull and some internal organs takes place through development of the branchial apparatus of the embryo. On each lateral wall of the pharyngeal gut there are five protrusions (branchial recesses), between which there are thickenings called the branchial arches. The first (maxillary) and second (hyoid) arches are called visceral, and the lower three — branchial arches. The fist visceral arch develops into the superior and inferior walls of the oral cavity, the maxilla and mandible, lips, small bones of the middle ear (malleus and incus) and muscles of mastication. Tissue of the second visceral arch develops into the lesser cornua and body of hyoid bone, styloid process of temporal bone, stapes bone of the middle ear and muscles of facial expression. The first branchial arch develops into the greater cornua of hyoid bone. The other branchial arches form the cartilages of the larynx. Epithelium of the first branchial recess forms the epithelial lining of the tympanic cavity, auditory tube, etc. The second branchial recess develops into epithelium of the tonsillar fossa; the third and fourth recesses — epithelial components of the thymus and parathyroid glands.

The tongue begins to form during week 5 of embryogenesis from one unpaired ectodermal germ, which forms its tip and middle part, and a pair of germs, which form the posterior part and its root. These germs gradually merge with each other. The papillae of the tongue form during months 6 and 7.

The teeth form from the ectoderm, which covers the maxillary and mandibular alveolar processes. An ectodermal dental plate (thickening) gradually lowers into the mesenchyme of these processes. The pulp of the teeth has a mesenchymal origin.

During the second month of embryogenesis the primitive gut undergoes complex changes. A primitive intestinal loop appears, its flexure directed towards the umbilical opening. The gut protrudes through this opening, forming a physiological umbilical hernia. During the fourth month the umbilical opening narrows and the intestinal loops are drawn back into the body cavity.

During the second month of embryogenesis the future stomach begins to form as a dilation of the anterior gut. Beneath the primitive intestinal loop appears a small protrusion of the gut, which later develops into the cecum. The descending part of the primitive loop develops into the small intestine, and the ascending part—into the large intestine. The beginning of the descending part develops into the duodenum, while the rest of it becomes mesenteric small intestine. All parts of the intestine continue

to grow and shift their position inside the abdominal cavity of the fetus (see below). Dorsally to the germ of the cecum form the future left colic flexure and transverse and descending colons. By month 6 of embryogenesis the ascending colon and right colic flexure appear. The end part of the large intestine develops into the sigmoid colon. The rectum emerges from the large intestine by formation of transverse septa in the wall of the cloaca. This septa divides the cloaca into a urogenital (anterior) and perineal (posterior) parts. After the breaking of the cloacal membrane the rectum becomes communicated with the outer environment.

Simultaneously with differentiation and growth, the different parts of the gut change their position within the future abdomen. During months 2 and 3 the posterior gut shifts out of the median plane upwards and to the left, in front of the intestinal loop. The intestinal loop turns 180 degrees clockwise. The germ of the cecum shifts upward and to the right, while the upper part of the intestinal loop shifts downward, behind the cecum. As the intestinal loop grows, the cecum germ becomes shifted downward, into the right iliac fossa. The intestinal loop forms a 90 degree flexure to the right. Its descending part becomes longer and forms numerous loops, which considerably shift the future large intestine. As a result, the ascending colon lies in the right part of the abdominal cavity, and the transverse colon lies across.

The peritoneal lining of the intestine develops together with formation of the mesentery of the primitive gut. During the first month of embryogenesis the truncal gut (below the diaphragm) is attached to the anterior and posterior walls of the embryo by the ventral and dorsal mesenteries, which originate from the splanchnopleura. The ventral mesentery below the umbilical foramen disappears at an early stage, while its upper part develops into the lesser omentum and the falciform ligament of the liver. The position of the dorsal mesentery is changed by the growing greater curvature of the stomach and its shift downward and to the right. As the stomach grows downward and shifts from a sagittal position into a transverse one, the dorsal mesentery protrudes from underneath its greater curvature, forming the greater omentum. The posterior part of the dorsal mesentery continues onto the posterior abdominal wall. The dorsal mesentery develops into mesenteries of the small and large intestines.

The anterior wall of the developing duodenum forms a pair of protrusions into the ventral mesentery, which later become the liver and gallbladder. The pancreas forms out of the merged ventral and dorsal endoderm protrusions into the dorsal mesentery. As a result of turning of the stomach and growth of the liver the duodenum and pancreas move into a retroperitoneal position and loose their mobility.

AGE CHARACTERISTICS OF THE DIGESTIVE SYSTEM ORGANS

Oral cavity. In newborns and in children several months old the oral cavity is very small, the vestibule is narrow and the hard palate is wide and flattened. The alveolar margins (processes) of the maxilla and mandible have two grooves. The medial (internal) groove corresponds to germs of the deciduous teeth, and the lateral (external) groove—to germs of the permanent teeth. The soft palate is sufficiently developed. The cheeks are prominent due to the presence of the adipose body, which later move to the back and gradually disappears. In the middle of the upper lip of newborns there is a tubercle, which is connected with the gingiva by a short frenulum. In the middle of the inferior lip there is an impression, which disappears with age. In newborns the teeth are absent. The mucosa of the oral cavity is relatively thick, although in the regions of the lips and cheeks it is thin and movable. The mucosa of the hard palate forms transverse palatine folds. A newborn has less small salivary glands than an adult.

Major salivary glands. The average mass of the sublingual gland of a newborn is 0.42 g; of the submandibular gland — 0.84 g; of the parotid gland — 1.8 g. These glands develop most intensely between the fourth month and second year of life, when they increase in size and mass, and their secretory compartments undergo final differentiation. These glands reach maximal development between ages 20 and 29. After the age of 60 years the amount of parenchyma decreases, while the amount of stroma tends to increase. Their excretory ducts increase in size and often form ampulla shaped dilations.

Tongue. In newborns the tongue is broad and thick, its size is disproportionate relative to the oral cavity. The border between the body and root of the tongue resembles a deep groove. The lingual frenulum is better developed than in adults. The muscles of the tongue are formed and the papillae are well developed and contain numerous taste buds. The mucosa of the tongue contains less glands then in an adult. At 1.5 years of age the tongue is 4–5 cm long and 3.5 cm wide. The size of the tongue gradually increases with age. During senescence the papillae atrophy and the mucosa becomes thin.

Pharynx. The pharynx of a newborn is relatively wide (1.2–1.5 cm) and is 4 cm long. At this age it is situated higher (especially the laryngopharynx) then in an adult. The pharyngeal openings of auditory tubes resemble fissures, and are situated at the level of the hard palate. The auditory tube lies horizontally, which makes it easier for infections to spread into the tympanic cavity. The vault of the pharynx in newborns is flattened and leans forward relative to the oropharynx. The choanae are weakly

developed. After birth, with intensive growth of the facial skull, the nasopharynx considerably increases in size. During puberty the pharynx primarily grows in length.

Oesophagus. In newborns the oesophagus resembles a thin tube 8–10 cm long. Flexures and constrictions are not yet formed (except for the diaphragmatic one). They appear at ages 5–6. At ages 1–2 years the length of the oesophagus reaches 10–12 cm, and its diameter — 0.5–0.6 cm. Mucosal folds appear in the oesophagus at two years of age. With age its skeletotopic boundaries shift downward. At ages 20–29 the length of the esophagus is 23–30 cm, and thickness of its walls is 500–800 mm. During senescence its length slightly increases, and its walls become thinner. The number of glands tends to decrease during this period.

Stomach. In newborns the stomach is spindle-shaped. Its fundus is weakly developed, the body is relatively wide, the pyloric region is narrow, and the angle between the fundus and abdominal esophagus (angle of His) is acute. The surface area of the mucosa is 40–50 cm^2, and the volume of the stomach is 30–35 cm^3. The muscularis is weakly developed. The glands of the mucosa are differentiated and contain a lot of epitheliocytes, which produce lipase and lactase for digestion of milk. After birth the stomach grows quite quickly. Its volume and mass increases by several times after just two weeks. The size and shape of the stomach in an adult, as well as its position, thickness of its walls and number of gastric glands are highly variable. After age 60 the stomach often shifts downward (gastroptosis).

Small and large intestines. The length of the intestine in newborns is 340–460 cm. During the first year of life it increases by 50 percent. The ratio between the lengths of the intestine and that of the body is 8.3:1 in newborns; 5.4:1 at one year; 7.6:1 at age 16; and 5.4:1 in adults. The ratio between the large and small intestines is 1:5 in newborns and 1:4 in adults. In children the duodenum is situated higher than in adults, and often has the shape of a ring. In newborns and nurslings the duodenum is relatively longer than in adults. The bile duct and pancreatic ducts open into its superior part. The beginning of the mesenteric part of the small intestine is situated higher than in adults (up to the level of the L1 vertebra). The ileocaecal valve is also situated relatively high, below the liver. By age 14 it descends into the iliac fossa. In elderly people it may be situated inside the lesser pelvis (colonoptosis).

The caecum of newborns is 1.7 cm wide and 1.5 cm in length. During the first years of life the appendix is relatively longer than in adulthood (4–5 cm in newborns). The ascending colon in newborns is short, and the right colic flexure is shifted to the right by the relatively large liver. The

transverse, descending and sigmoid colons are relatively long. The length of the transverse colon reaches 20 cm, and of its mesentery — 2 cm. The descending colon is approximately 5 cm long. The sigmoid colon (20 cm long) lies high in the abdominal cavity and has a long mesentery. A wide loop of this colon extends to and adjoins the rectum. By age 5 the sigmoid colon lowers into the inlet of the lesser pelvis. The rectum of a newborn is 5–6 cm long, and its ampulla and flexures are not expressed until ages 4–7. The most active growth of the rectum takes place after age 8.

In newborns the villi of the small intestine are short, and their number is less than in adults. Folds of the small and large intestine (except for anal columns) are weakly developed. The haustra, taeniae coli and epiploic appendages of the large intestine are not well expressed and develop during ages 4–5. The number of intestinal glands is less than in adults. The submucosa is very loose especially in the end parts of the large intestine. The maximal surface area of mucosa, length, number of glands and other parameters of the intestine are reached between ages 20 and 49. During senescence the taeniae coli become thin, the haustra and folds decrease in number and size, and the total number of intestinal glands becomes less.

Liver. In newborn children the liver is relatively large and movable. It occupies more than half of the abdominal cavity. It weights approximately 135 g, which is 4–4.4 percent of the body mass (in adults the liver makes up 2–3 percent of total weight). The longest transverse size of the liver in newborns is 11 cm; longest longitudinal size is 7 cm; longest vertical size is 8 cm. The left lobe of the liver is as large as the right one (sometimes larger). Its inferior margin protrudes 2.5–4.0 cm from underneath the costal arch, occasionally reaching the iliac crest. The relative size of the liver decreases with age, although its absolute size increases. At age 7 its inferior margin no longer extends below the costal arch, and its mass reaches 700 g. The liver reaches its final size between ages 20–29. After 70 years its mass decreases, and its connective tissue expands. Hepatocytes contain an increased amount of lipofuscin. The number of dividing hepatocytes becomes less, and their nuclei become bigger.

The gallbladder in newborns is approximately 3–3.2 cm long and 1 cm wide. Its fundus does not extend below the inferior liver margin. At this age the gallbladder projects onto the anterior abdominal wall below the costal arch, 2 cm to the right of the anterior median line. By ages 10–12 the volume of the gallbladder doubles. It reaches its final size by 20–25 years. During senescence there is thinning of its walls, which may form diverticula (especially in the region of its neck).

The pancreas of a newborn is approximately 4–5 cm long and weights 2–3 g. It is situated higher than in an adult. In newborns it is less fixed to the

abdominal wall, and is therefore more movable. It receives an abundant blood supply; its endocrine component is well expressed, while its exocrine part is still underdeveloped. The position of the pancreas relative to other organs, as is characteristic for adults, becomes established by age one. At age 3 the mass of the gland reaches 20 g, and by ages 10–12 it is 30 g.

Peritoneum. In newborns the peritoneum is thin and colorless. The submesothelial connective tissue layer is continuous. Later it gains a lacy appearance, resembling a network of connective tissue septa with blood vessels. The lesser omentum is well developed, and the epiploic foramen is relatively large. Recesses and folds of parietal peritoneum are well developed at this age, especially on the front abdominal wall. The greater omentum in newborns is short, and covers the small intestine loops only partially. With age the greater omentum becomes longer, thickens and accumulates a large amount of adipose tissue and lymphoid nodules. Often with age, especially in elderly people, adhesions may form between the parietal and visceral sheets of peritoneum, which may have an effect on the functioning of organs.

Questions for revision and examination

1. Describe the first stages of development of the digestive system (during first and second months of embryonic development).

2. Describe the changes, which take place after birth in structures of the oral cavity and its organs, pharynx and esophagus.

3. What age characteristics (changes) of the stomach, small and large intestine can you name?

4. Describe the age characteristics of the liver, gallbladder, pancreas and peritoneum.

VARIANTS AND ANOMALIES OF THE DIGESTIVE ORGANS

Lips. Total or partial cheiloschisis (cleft lip) may occur on the upper lip, usually lateral of the median groove (condition known as «harelip»). Sometimes the cleft extends to the wing of the nostril. Very rarely this fissure reaches the olfactory region of the nose or, avoiding the nostril wing, reaches the orbit and splits the lower lid. The lower lip may also be cleft. A very rare condition is an absence of one or both lips. The mouth fissure may be asymmetrically extended into one or both sides (macrostomia). It may also be narrowed (microstomia).

Palate. Cleft palate is a defect of the hard palate. It may be combined with cleaving of the soft palate. There are also various combinations of cleft palate and cleft lip. Sometime during this condition the alveolar process of the maxilla becomes separated from the rest of the bone by a deep fissure from one or both sides. Sometimes the uvula may be cleft. There

are also cases when the uvula is displaced to one side or when its base begins on the posterior edge of the vomer. The shape and size of the uvula are variable. Muscle of the soft palate may very depending on the extent of non-union of the two halves of the palate. Sometimes there is a pterygotubal muscle, which originates from the medial pterygoid muscle. The pterygotubal muscle is inserted into the mucosa of the auditory tube. Often, inside the palatine aponeurosis there is a minor elevator muscle of the soft palate, which originates from the hook of the sphenoid bone.

Teeth. The number of teeth and their position are subject to considerable variability. Between the crown and root of medial incisors there is often a thickened enamel ring, which forms from the pressure of the antagonist tooth. On the internal surface of upper lateral incisors, near the back of their root, there is sometimes a tubercle. The canines (especially inferior) are often twisted about their axis and turned outward. In rare cases the canine may not erupt. Sometimes the canines develop after the adjacent teeth and, due to a lack of space, grow sideways. The premolars may be partially or completely absent. The number of roots of molars may vary. Often their roots converge together or diverge into different directions. Often the upper molars (especially second molars) have additional masticatory tubercles. The third molars (wisdom teeth) may not erupt, or may appear only after age 30. Sometimes there are accessory teeth, which are situated on the side of the gingiva. There are many possible variations of occlusion.

Tongue. Very seldom the tongue is absent (aglossostomia). The foramen cecum is absent in 7 percent of cases. The apex of the tongue may be cleft into two or three tips. There may be accessory muscles, such as the triticeoglossal muscle, which originates on the cartilago triticea of the larynx. There may also be an additional middle longitudinal muscle, accessory cornuoglossal or auriculoglossal muscles.

Cheeks. The size of the adipose body is highly variable, as well as the configuration of the cheek, thickness of the buccinator muscle and its origin and insertion.

Major salivary glands. There may be an accessory parotid gland near the anterior margin of the masseter muscle. Its excretory duct may open separately, but more often connects with the parotid duct. There may also be additional glandular lobules near the submandibular gland, by the lateral edge of the geniohyoid muscle. Sometimes there are additional sublingual glands. The number of small sublingual ducts varies between 18 and 30.

Pharynx. Very seldom the pharynx may be absent. One of its parts may have a narrowing or be interrupted. Sometimes there is a fistula between the pharynx and outside (branchiogenic fistulae), which correspond

to unclosed branchial fissures. These fistulae may open by the posterior edge of the sternocleidomastoid muscle, above the sternoclavicular joint or near the mastoid process of the temporal bone. There are variations of the pharyngeal muscles. The inferior constrictor muscle of the pharynx has accessory fascicles, which extend from the trachea. In 4 percent of cases there is a ligamentopharyngeal muscle, which originates on the lateral thyrohyoid ligament and is inserted into the median or inferior pharyngeal constrictor. In 60 percent of cases there is a cricopharyngeal muscle, which sometimes gives an origin to the elevator muscles of the thyroid gland, which stretches to the right and left lobes of this gland. There are often muscle fascicles stretching between the middle constrictor of the pharynx and the intermediate tendon of the digastric muscle. The pharyngobasilar fascia is sometimes partially or completely replaced by an unpaired muscle, which attaches the pharynx to the skull. The stylopharyngeal muscle may be partially doubled. It often combines with accessory fascicles, which originate from the mastoid process (mastoidopharyngeal muscle) or on the surface of the occipital bone (occipitopharyngeal muscle). In the vault of the pharynx the mucosa may form one or several recesses 1.5 cm long and 0.5 cm wide (pharyngeal bursa). The pharyngeal bursa may be communicated with the pharyngeocranial canal.

Oesophagus. In rare cases the oesophagus may be absent; there may be closure of its lumen (atresia) or congenital diverticula. A very rare condition is a doubling of the oesophagus or existence of fistulae into the trachea. Occasionally there are fistulae from the oesophagus, which open on the skin of the lower neck region (near the front edge of the sternocleidomastoid muscle). The development of the muscularis of the oesophagus may vary. The transition between smooth and striated parts of the muscle layer may be located in different parts of the oesophagus. There may be bronchoesophageal or pleuroesophageal muscles. In 30 percent of cases in the lower section of the posterior mediastinum, behind and to the right of the oesophagus, there is a paraesophageal bursa 1.65–4 cm long. In 10 percent of cases the aorta and oesophagus pass through the diaphragm in a common foramen. The direction of the oesophagus, its flexures, extent and size of its constrictions are considerably variable.

Stomach. Very rarely the stomach is absent or doubled. There may be partial of complete transverse strangulations of its lumen, which may vary in shape and size. More often they are situated near the pyloric region. There are variations in thickness of the muscular layer of the stomach and the number and distribution of its glands.

Small intestine. There are many variants of shape and position of the duodenum. Aside from the typical horseshoe shape it may be shaped like a full or partial ring. Sometimes it lacks the horizontal or the descending part.

In very rare cases the small intestine may be absent. More often only one of its parts is missing. Its diameter and length are highly variable. It may be significantly lengthened (dolichocholia) or shortened (brachicholia). Occasionally there are cases of atresia, strangulation or diverticula in various sections of the intestine. In 2 percent of cases there is an occurrence of Meckel's diverticulum, which is a remainder of the omphalomesenteric duct of the fetus. Meckel's diverticulum occurs in free, open or closed forms. The more common is the free form, when there is a protrusion of the ileum on the side opposite from the mesentery. The diverticulum is situated approximately 60–70 cm away from the ileocecal valve. Its length varies between several millimeters and 5–8 cm, although there has been a case when it reached 26 cm. The open form of Meckel's diverticulum is a tube, which connects the intestine with an opening of the umbilicus (congenital intestinal fistula). In cases of closed Meckel's diverticulum a canal, which is closed at both ends, remains between the umbilicus and the intestine (incomplete closure of the omphalomesenteric duct). In rare cases there is a sack-like remnant of the omphalomesenteric duct, situated inside or near the umbilicus and not connected with the intestine. Another possible anomaly is a congenital umbilical hernia, which occurs when the loop of the embryonic intestine remains protruding through the umbilical ring.

Sometimes the mesentery contains muscle fascicles, which extend from the anterior surface of the spine. Occasionally the small and large intestine have a common mesentery.

Large intestine. In very rare cases the large intestine may be absent or partially doubled. More often there are constrictions of its lumen. Occasionally there may be atresia of the rectum, which may or may not be combined with fistulae into neighboring organs. There are variations of congenital dilation and doubling of part or all of the large intestine, which is followed by a constricted zone (aganglionic megacolon, or Hirschsprung's disease). The length ratios of different parts of the large intestine vary between individuals. In cases of total dolichomegacolon (11 percent) the entire colon has a mesentery and lies in an intraperitoneal position; the intestine is increase in length and width. In 2.25 percent of cases there is a general ptosis of the colon (colonoptosis), during which the entire large intestine lies almost as low as the lesser pelvis. There may also be lengthening or ptosis of different parts of the colon.

In the rectum there is sometimes a third (superior) sphincter, which is situated at the level of its transverse fold. If the cloacal membrane does not rupture there may be atresia of the anal opening.

Liver. The shape and size of the right and, especially, left lobes vary between individuals. Often segments of the liver tissue surround the inferior vena cava or round ligament. Sometimes the liver may have additional lobes (5–8). There have been cases in literature of a small additional liver, situated near the visceral surface of the main liver, next to its posterior or anterior margin. The ligament of the inferior vena cava often contains blind bile ducts.

Gallbladder. Sometimes the gallbladder is completely covered by peritoneum and has a short mesentery. In very rare cases it may be absent of doubled. The cystic duct occasionally opens into the left or right hepatic duct. There are many variations (over 15) of mutual position of the pancreatic and common bile ducts, especially of their distal parts, before opening into the duodenum.

Pancreas. The lower part of its head is sometimes elongated and curves around the superior mesenteric vein. Very seldom there is an accessory pancreas (3 cm in cross section), which may be situated inside the wall of the stomach, duodenum, jejunum or mesentery of the small intestine. Occasionally there may be several accessory pancreatic glands, which may be up to several centimeters long. The position of the main pancreatic duct is highly variable. The accessory duct may have an anastomosis with the main duct, or may be atretic or absent. In rare cases the pancreas has the form of a ring, situated around the duodenum. There have been cases of shortening and doubling of its tail part.

A very rare condition is partial or complete visceral inversion of organs (situs viscerus inversus), or Kartagener's syndrome. During this condition the liver lies on the left, the heart and spleen—on the right, and so on. Full visceral inversion occurs in one birth in a million.

Questions for revision and examination

1. Name the variations and anomalies of organs of the oral cavity, pharynx and esophagus.
2. Describe the variants and anomalies of the stomach, small and large intestine, liver and pancreas.

THE RESPIRATORY SYSTEM

The respiratory system provides the organism with oxygen and removes carbon dioxide. It consists of respiratory passages and the lungs. The respiratory passages are divided into upper and lower sections. The upper respiratory passages include the nasal cavity, nasopharynx and oropharynx.
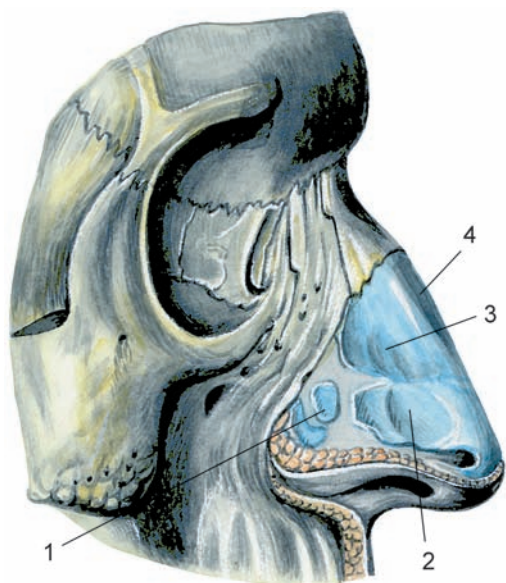
The lower respiratory passages consist of the larynx, trachea, bronchi (bronchial tree). Inside the respiratory passages air is warmed, moistened and cleared of extraneous particles. The lungs are the sites of respiratory gas exchange. Oxygen diffuses from the alveoli into blood capillaries, while carbon dioxide diffuses from the blood stream into the alveoli.

NOSE

The nasal region includes the external nose and the nasal cavity.

The outer nose (násus extérnus) consists of the root, dorsum, apex and wings of the nose. The root is situated in the upper part of the face, and is separated from the forehead by the nose bridge. The d o r s u m   o f   t h e   n o s e extends along the median line, below the bridge, and ends as the apex, or tip. The lower side parts of the nose form its ala, which limit the nares (nostrils). The nostrils are divided along the median line by the m e m b r a n o u s   p a r t of the nasal septum. The root and upper part or the dorsum of the nose are formed by nasal bones and frontal processes of the maxillae. The middle part of dorsum and side parts of the nose are formed by the paired l a t e r a l   c a r t i - l a g e of the nose (Fig. 152). At the bottom each lateral cartilage of nose connects with the m a j o r   a l a r   c a r t i l a g e, which limits the nostrils from the front and side. There are also 2–3 m i n o r   a l a r   c a r - t i l a g e s, situated at each side behind the major alar cartilage. Between the lateral greater alar cartilages there are often small a c c e s s o r y (sesamoid) nasal cartilages. The inside surface of the dorsum adjoins the septal n a s a l   c a r t i l a g e. This is an unpaired cartilage of an incorrect tetragonal shape. In the back this cartilage connects with the perpendicular lamina of the ethmoid bone, vomer and anterior nasal spine. Below the inferior margin of the vomer there is a narrow v o m e r o n a -

Fig. 152. Cartilaginous and osteal skeleton of external nose.

1 — minor alar cartilage; 2 — major alar cartilage; 3 — lateral nasal cartilage; 4 — septal nasal cartilage.

s a l   c a r t i l a g e. Nasal cartilages are covered by perichondrium, and are connected with each other and adjacent structures by connective tissue.

Nasal cavity

The nasal cavity (cávum nási) is divided into right and left halves by the n a s a l   s e p t u m. In the back it communicates through the c h o a n a e with the nasopharynx. The nasal septum consists of a membranous, cartilage and b o n y   p a r t s. Its m e m b r a n o u s   and c a r t i l a g i n o u s p a r t s are movable. Each half of the nasal cavity consists of a v e s t i - b u l e (in the front) and a nasal cavity proper. The vestibule is limited at the top by a small eminence called the l i m e n   n a s i, which is formed by the upper edge of the major alar cartilage. Merged with the side walls of the nasal cavity are the nasal conchae (Fig. 153). Beneath the s u p e r i o r, m i d d l e   and i n f e r i o r   n a s a l   c o n c h a e are recesses called the s u - p e r i o r, m i d d l e   and i n f e r i o r   n a s a l   m e a t u s e s, respectively. The s u p e r i o r nasal meatus extends only through the posterior part of the nasal cavity. Between the nasal septum and medial edges of the nasal
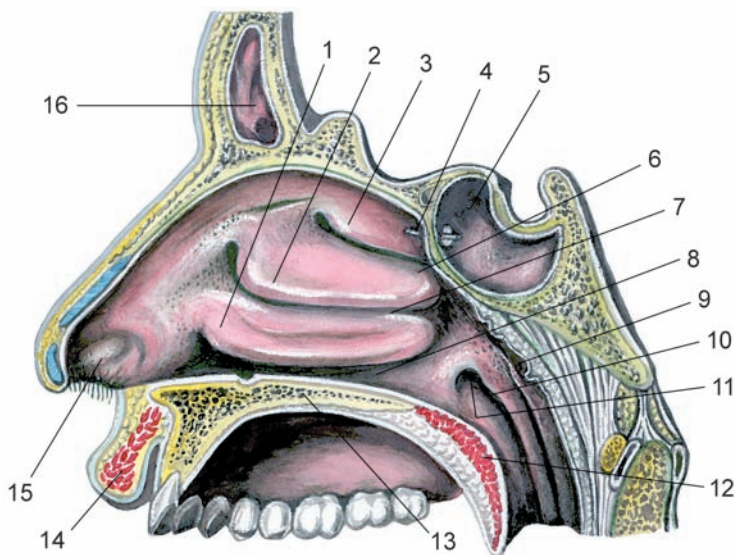
Fig. 153. Nasal cavity. Nasal conchae are removed.

1 — inferior nasal concha; 2 — middle nasal concha; 3 — superior nasal concha; 4 — aperture of sphenoidal sinus; 5 — sphenoidal sinus; 6 — superior nasal meatus; 7 — middle nasal meatus; 8 — inferior nasal meatus; 9 — pharyngeal tonsill; 10 — torus tubarius; 11 — pharyngeal opening of auditory tube; 12 — soft palate; 13 — hard palate; 14 — upper lip; 15 — nasal vestibule; 16 — frontal sinus and a probe within its aperture.

conchae, on each side, is a c o m m o n n a s a l m e a t u s. The superior nasal meatus communicates with the sphenoid sinus and posterior cells of the ethmoid bone. The middle nasal meatus communicates with the frontal sinus (through the ethmoid infundibulum), maxillary sinus (through the semilunar fissure), and anterior and middle cells of the ethmoid bone. Through the sphenopalatine foramen the middle nasal meatus also communicates with the pterygopalatine fossa. The inferior nasal meatus communicates through the nasolacrimal duct with the orbit.

The m u c o s a of the nasal vestibule is lined with squamous epithelium, which is a continuation of the skin. Beneath this epithelium lie sebaceous glands and hair roots. The nasal cavity is divided into r e s p i r a t o - r y and o l f a c t o r y r e g i o n s. The olfactory region includes the superior nasal conchae and upper parts of the middle nasal conchae and nasal septum. This region is lined by ciliary pseudostratified epithelium, which contains bipolar sensory cells. The epithelium of the rest of the nasal cavity (respiratory region) contains large numbers of goblet cells, which produce mucus. The mucus covers the epithelium and moistens incoming air. Movement of cilia helps to remove mucus and the precipitated foreign particles. The l a m i n a p r o p r i a of the mucosa is thin, and contains a lot of elastic fibers, as well as mucous and serous glands. Inside the lamina propria lie numerous blood vessels, especially thin walled veins, which help warm incoming air. The m u s c u l a r i s m u c o s a e is weakly developed. The submucosa is thin, and contains vessel and nerve plexuses, lymphoid tissue, mast cells and other cell elements.

Air passes through choanae into the nasal and oral parts of the pharynx, and into the larynx. The structure of the pharynx is described above.

I n n e r v a t i o n of the nasal mucosa: sensitive — anterior ethmoidal nerve from nasociliary nerve (anterior part of nasal cavity); nasopalatine nerve and posterior nasal branches of maxillary nerve (posterior part of lateral wall and septum of nasal cavity). Glands of the nasal cavity receive innervation from the pterygopalatine node.

B l o o d s u p p l y: sphenopalatine artery (from maxillary artery), anterior and posterior ethmoidal arteries (from ophthalmic artery).

V e n o u s o u t f l o w: sphenopalatine vein (into pterygoid plexus).

L y m p h o u t f l o w: submandibular and mental lymph nodes.

LARYNX

The larynx (lárynx) performs respiratory and vocal functions. It is shaped like an incorrect tube, which is dilated at the top and narrowed at the bottom. The upper border of the larynx is situated at the lower edge level of the C4 vertebra; the lower border — at the lower edge level of the

C6 vertebra. It is situated in the anterior region of the neck. At the top it is attached to the hyoid bone. At the bottom it continues into the trachea. In front the larynx is covered by the pretracheal and superficial laminae of the cervical fascia and by the infrahyoid group of neck muscles. At the front and side it is covered by the left and right lobes of the thyroid gland. Behind the larynx lies the laryngopharynx. The connection between the larynx and pharynx can be linked to their common origin (epithelium and glands) from the ventral wall of the pharyngeal section of the primitive gut. As a result, the pharynx pertains to both the respiratory and digestive systems.

The larynx is divided into the vestibule, interventricular section and subvocal cavity (Fig. 154). The l a r y n g e a l v e s t i b u l e is situated be-

Fig. 154. Laryngeal cavity. Larynx is opened from its posterior side.

1 — greater horn of hyoid bone; 2 — triticeal cartilage; 3 — thyrohyoid membrane; 4 — supeior horn of thyroid cartilage; 5 — vestibular fold; 6 — laryngeal ventricle; 7 — vocal fold; 8 — cricoarytenoid joint; 9 — infraglottic cavity; 10 — lamina of cricoid cartilage (partially removed); 11 — posterior cricoarytenoid muscle; 12 — arytenoid cartilage; 13 — corniculate cartilage; 14 — vestibulum of larynx; 15 — lateral thyrohyoid ligament; 16 — epiglottis.

tween the entrance into the larynx and the vestibular folds (false vocal cords). The space between the vestibular folds is called the r i m a v e s t i b u l i. The front wall of the vestibules is formed by the epiglottis, and the back wall — by the arytenoid cartilage (see below). The interventricular section is very short, and is confined by the vestibular folds at the top, and v o c a l f o l d s at the bottom (Fig.155). Between these folds, on the right and left walls, there is a recess called the laryngeal ventricle. The space between the right and left vocal folds is called the r i m a g l o t t i d i s. In

Fig. 155. Conus elasticus of larynx. Vocal ligaments and rima glottidis. Superior aspect.

1 — thyroid cartilage; 2 — vocal fissure (intermembranous part); 3 — vocal process of arytenoid cartilage; 4 — rima glottidis (intercartilagineal part); 5 — muscular process of arytenoid cartilage; 6 — posterior cricoarytenoid ligament; 7 — superior horn of thyroid cartilage; 8 — corniculate cartilage; 9 — conus elasticus; 10 — vocal ligament.

males this fissure is 20–24 mm long, and in females — 16–19 mm. The average width of the vocal fissure during breathing is 5 mm. During speech formation it is wider. Most of the vocal fissure in the front is called i n t e r m e m - b r a n o u s, and in the back — i n t e r c a r t i l a g i n o u s p a r t (situated between arytenoid cartilages). The i n - f r a g l o t t i c c a v i t y extends from the vocal folds to the opening of the trachea.

The larynx is formed by **paired** and **unpaired cartilages**, which are connected with ligaments, joints and muscles. The thyroid and cricoid cartilages and the epiglottis are unpaired. The arytenoid, corniculate, cuneiform and inconstant triticea cartilages are paired (Fig. 156).

The t h y r o i d c a r t i l a g e (cartilágo thyroídea) is the largest cartilage of the larynx. It is formed by two tetrahedral plates, which are connected along the median line at an angle to each other. This angle is approximately 120 degrees in females and 90 degrees in males. In men this angle forms a l a r y n g e a l p r o m i n e n c e called the Adam's apple. The r i g h t and l e f t l a m i n a e s of this cartilage extend sideways to the back, forming a sort of shield. On the upper margin of the cartilage, above the laryngeal protrusion, is the deep s u p e r i o r t h y r o i d n o t c h. On the lower margin is a very slight i n f e r i o r t h y r o i d n o t c h. From the posterior margins extend the long s u p e r i o r and shorter i n f e r i o r h o r n s of the thyroid cartilage. On the external surface of each plate there is an o b l i q u e l i n e, which is a site of attachment of muscles.

The c r i c o i d c a r t i l a g e (cartilágo cricoídea) is shaped like a ring. It consists of an a r c h and a quadrangular l a m i n a. The upper lateral edges of this plate are surfaces, which articulate with the arytenoid cartilages. On the sides of the cricoid cartilage plate there are articular surfaces, which articulate with the inferior horns of the thyroid cartilage.
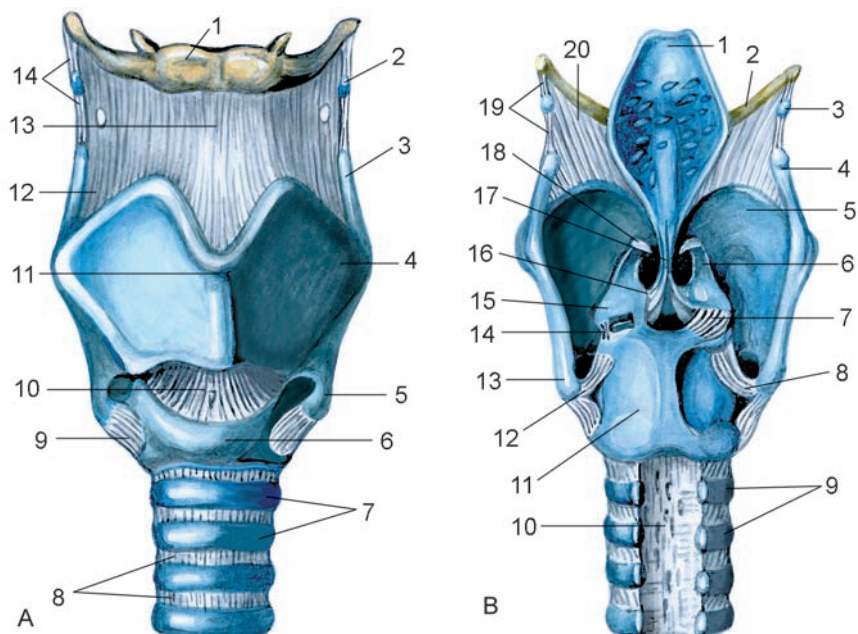
Fig. 156. Cartilages; ligaments and joints of larynx.

A — anterior aspect. 1 — body of hyoid bone; 2 — triticeal cartilage; 3 — superior horn of thyroid cartilage; 4 — plate of thyroid cartilage; 5 — inferior horn of thyroid cartilage; 6 — arch of cricoid cartilage; 7 — tracheal cartilages; 8 — anular ligaments; 9 — cricothyroid joint; 10 — cricothyroid ligament; 11 — superior thyroid notch; 12 — thyrohyoideus membrane; 13 — middle thyrohyoid ligament; 14 — lateral thyrohyoid ligament.

B — posterior aspect; 1 — epiglottis; 2 — greater horn of hyoid bone; 3 — triticeal cartilage; 4 — superior horn of thyroid cartilage; 5 — plate of thyroid cartilage; 6 — arytenoid cartilage; 7 — right cricoarytenoid joint; 8 — right cricothyroid joint; 9 — tracheal cartilagea; 10 — membranose wall; 11 — plate of cricoid cartilage; 12 — left cricoarytenoid joint; 13 — inferior horn of thyroid cartilage; 14 — left cricoarytenoid joint; 15 — muscular process of arytenoid cartilage; 16 — vocal process; 17 — thyroepiglotical ligament; 18 — corniculate cartilage; 19 — lateral thyrohyoid ligament; 20 — thyrohyoid membrane.

The arytenoid cartilage (cartílago arytenoídea) resembles a pyramid, the apex of which is turned to the top. From the front of its base protrudes a short vocal process and, laterally, a muscular process. The arytenoid cartilage has an anterolateral, medial and posterior surfaces.

The epiglottis (epiglóttis) has the shape of a leaf. It is very flexible and elastic. It has a narrowed inferior part, called the stalk, and a broad rounded superior part. The epiglottis is situated above the entrance into the larynx. Its anterior surface faces the root of the tongue; the posterior surface faces the vestibule of the larynx.

The corniculate cartilage (cartilágo corniculáta) is situated over the apex of the arytenoid cartilage, forming a corniculate tubercle.

The cuneiform cartilage (cartilágo cuneifórmis) is small; it is situated inside the aryepiglottic fold, in the form of a small cuneiform tubercle.

The triticea cartilage (cartilágo trit icea) is not always present. It is very small and lies inside the aryepiglottic fold.

Cartilages of the larynx are movable, due to the presence of two paired joints. The paired cricothyroid joint is formed between the inferior horn of the thyroid cartilage and articular surface on the anterolateral side of the cricoid cartilage. Movement in this joint takes place about the frontal axis (the thyroid cartilage bends forward and returns back). During this movement the distance between the angle of the thyroid cartilage and base of the arytenoid cartilage increases. The cricoarytenoid joint is formed by the articular surface on the base of the arytenoid cartilage and the upper lateral margin of the cricoid cartilage plate. The two cricoarytenoid
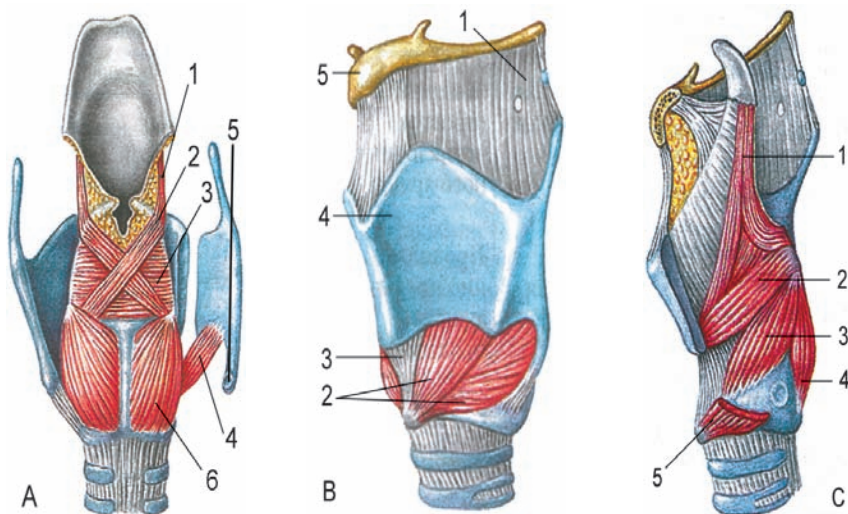
Fig. 157. Muscles of larynx.

A — posterior aspect (with part of right plate of thyroid cartilage pulled aside) 1 — ary-epiglottical muscle; 2 — oblique arytenoid muscle; 3 — transverse arytenoid muscle; 4 — cricothyroid muscle; 5 — cricoarytenoid joint; 6 — posterior cricoarytenoid muscle. B — anterior and partly lateral aspects. 1 — thryreohyoid membrane; 2 — cricothyroid muscle; 3 — cricothyroid ligament; 4 — thyroid cartilage; 5 — hyoid bone. C — lateral aspect (left lamina of thyroid cartilage is removed): 1 — thyroepiglottic muscle; 2 — thyroarytenoid muscle; 3 — lateral cricoarytenoid muscle; 4 — cricoid cartilage; 5 — cricothyroid muscle.

joints move simultaneously about the vertical axis. When the arytenoid cartilages are turned to the inside, their vocal processes move towards each other and the vocal fissure closes. When these cartilages are turned to the outside the vocal processes move away from each other and the vocal fissure widens. The arytenoid cartilages can also undergo slight gliding movements over the plate of the cricoid cartilage. When they glide toward each other, the posterior section of the vocal fissure narrows; when they glide away from one another, it widens.

Aside from joints, the cartilages of the larynx are connected by ligaments. The t h y r o h y o i d   m e m b r a n e hangs the larynx onto the hyoid bone, attaching to the upper margin of the thyroid cartilage. The thyrohyoid membrane thickens towards the middle, forming the m e d i a n   t h y r o h y o i d   l i g a m e n t. The sides of the membrane form the right and left l a t e r a l   t h y r o h y o i d   l i g a m e n t s. The anterior surface of the epiglottis attaches to the hyoid bone by the h y o e p i g l o t t i c   l i g a m e n t, and to the thyroid cartilage — by the t h y r o e p i g l o t t i c   l i g a m e n t. The m e d i a n   c r i c o t h y r o i d   l i g a m e n t begins on the arch of the cricoid cartilage and attaches to the inferior margin of the thyroid cartilage. The c r i c o t r a c h e a l   l i g a m e n t attaches to the lower margin of the cricoid cartilage arch with the first tracheal cartilage.

Muscles of the larynx are divided according to their function into dilators of the vocal fissure, constrictors of the vocal fissure and tensor muscles of vocal cords (Fig. 157). All muscles of the larynx (except for the transverse arytenoid muscle) are paired (Table 18).

Table 18. Muscles of the larynx.

Muscle	Origin	Insertion	Action	Innervation
Tensor muscles of vocal cords				
Cricothyroid	Anterior surface of the arch of the cricoid cartilage	Inferior border of the plate and inferior horn of thyroid cartilage	Bends the thyroid cartilage to the front	Superior laryngeal nerve
Vocal muscle	Angle of thyroid cartilage	Vocal process of arytenoid cartilage and vocal legaments	Pulls vocal legament forward and to the back (stretches it)	Inferior laryngeal nerve
Dilator muscles of vocal fissure				
Posterior cricoarytenoid	Posterior surface of the cricoid lamina	Muscular process of the arytenoid cartilage	Pulls muscular process to the back, turning the vocal process laterally	Inferior laryngeal nerve

Lateral cricoarytenoid	Superior border of the cricoid cartilage arch	Muscular process of arytenoid cartilage	Pulls muscular process of arytenoid cartilage forward, turning the vocal process medially	Inferior laryngeal nerve
Transverse arytenoid (unpaired)	Lateral border of the arytenoid cartilage	Lateral border of the arytenoid cartilage of opposite side	Pulls right and left arytenoid cartilages toward each other	Same as above
Oblique arytenoid	Muscular process of arytenoid cartilage	Apex of other arytenoid cartilage	Same as above	Same as above
Aryepiglottic	Continues from the previous muscle	Edge of epiglottis	Pulls epiglottis to the back, closing the laryngeal inlet	Same as above

The rima glottidis is dilated by the p o s t e r i o r c r i c o a r y t e n o i d m u s c l e. This muscle originates from the back of the cricoid cartilage plate, extends upward and laterally and is inserted into the muscular process of the arytenoid cartilage. During contraction it pulls the muscular process backwards, turning the arytenoid cartilage to the outside. The vocal process moves laterally, widening the rima glottidis.

C o n s t r i c t o r s o f the r i m a g l o t t i d i s include the lateral cricoarytenoid, thyroarytenoid, transverse and oblique arytenoid muscles. The l a t e r a l c r i c o a r y t e n o i d m u s c l e originates on the lateral part of the cricoid cartilage arch. It extends upward and to the back, and attaches to the muscular process of the arytenoid cartilage. During its contraction the muscular process moves forward, while the vocal process shifts inwardly, narrowing the rima glottidis (especially its anterior section). The t h y r o a r y t e n o i d m u s c l e originates from the inner surface of the thyroid cartilage, extends upward and to the back, and inserts on the muscular process of the arytenoid cartilage. These muscles also pull the muscular process forward, bringing the vocal processes together and closing the vocal fissure. The t r a n s v e r s e a r y t e n o i d m u s c l e is situated on the posterior surface of the two arytenoid cartilages. During contraction it brings these two cartilages closer, narrowing the posterior section of the rima glottidis. The o b l i q u e a r y t e n o i d m u s c l e passes in the form of separate fascicles from the posterior surface of the muscular process upward and medially to the lateral edge of the other arytenoid cartilage. Fascicles of the right and left oblique arytenoid muscles cross behind the transverse arytenoid muscle. During contraction they draw the arytenoid

cartilages toward each other. Separate fascicles from these muscles continue inside the a r y e p i g l o t t i c   f o l d and are inserted into the lateral edges of the epiglottis, forming the a r y e p i g l o t t i c   m u s c l e. These fascicles narrow the laryngeal inlet. The aryepiglottic muscles bend back the epiglottis, closing the larynx, during the act of swallowing.

The v o c a l   l i g a m e n t s   a r e   t e n s e d (s t r e t c h e d) by the cricothyroid and vocal muscles. The c r i c o t h y r o i d   m u s c l e originates from the anterior surface of the cricoid cartilage arch. It has a s t r a i g h t   and o b l i q u e   p a r t s. The straight part inserts on the inferior margin of the thyroid cartilage, and the oblique part — on its inferior horn. These muscles cause movement in the cricothyroid joint, bending the thyroid cartilage forward. The distance between this cartilage and the vocal processes increases and the vocal ligaments become tensed. Returning of the thyroid cartilage into its initial position relaxes the vocal ligaments. The v o c a l   m u s c l e (i n t e r n a l   t h y r o a r y t e n o i d   m u s c l e) is situated inside the homonymous fold. It originates on the lateral surface of the vocal process of the arytenoid cartilage and is insered into the inner surface of the thyroid cartilage angle. Part of its fascicles weaves into the focal cord. This muscle can contract totally or by separate fascicles, thus stretching the entire vocal cord or only parts of it.

The larynx is formed by three layers, including mucosa, fibrocartilaginous layer and adventitia. The m u c o s a   is lined primarily with stratified ciliary epithelium. Only the vocal cords are covered by stratified squamous epithelium. The lamina propria of mucosa is formed by loose connective tissue, and contains a lot of elastic fibers, which lie in no particular arrangement. These elastic fibers weave into the perichondrium. Inside the lamina propria lie numerous mixed glands. There is an especially high concentration of them in the region of the vestibule and ventricles of the larynx. In the region of the vocal ligaments glands are absent. The lamina propria also contains a lot of lymphoid formations. There are especially large accumulations of lymphoid tissue in the walls of the ventricles. The muscularis mucosa is almost undeveloped. The submucosa is thickened by a considerable content of fibrous and elastic fibers (f i b r o e l a s t i c   m e m b r a n e). This fibroelastic membrane is divided into two parts called the q u a d r a n g u l a r   m e m b r a n e and the elastic cone. The q u a d r a n g u l a r   m e m b r a n e corresponds to the vestibule of the larynx. Its superior margin reaches the aryepiglottic folds. Its free lower margin forms, on each side, the vestibular ligament of the larynx. The right and left vestibular ligaments lie inside the homonymous folds. The e l a s t i c   c o n e corresponds to the subvocal cavity region. Its free upper margin is thickened and stretched between the thyroid cartilage angle and the vocal processes, forming the vocal ligaments.

The f i b r o c a r t i l a g i n o u s layer consists of the hyaline and elastic cartilages of the larynx. The epiglottis, cuneiform and corniculate cartilages and the vocal processes of arytenoid cartilages are elastic. The thyroid, cricoid and arytenoid cartilages are hyaline.

The a d v e n t i t i a of the larynx is formed by loose fibrous connective tissue.
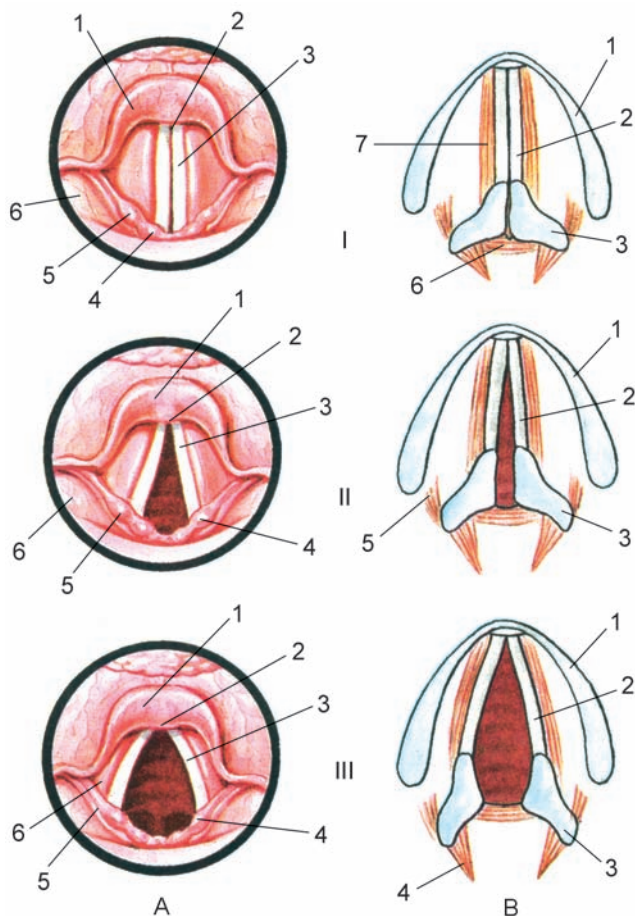
Fig. 158. Position of vocal ligaments during various functional stages of larynx. Rima glottidis is closed(I), opened(II), and widelydilatated (III).

A — laryngoscpopic picture; 1 — epiglottis; 2 — epiglottic tubercle; 3 — vocal fold; 4 — corniculate tubercle; 5 — cuneiform tubercle; 6 — vestibular fold. B — scheme of various positions of vocal ligaments, rima glottidis and arytenoid cartilages; 1 — right lamina of thyroid cartilage; 2 — vocal fold; 3 — arytenoid cartilage; 4 — posterior cricoarytenoid muscle; 5 — lateral cricoarytenoid muscle; 6 — transverse arytenoid muscle; 7 — thyroarytenoid muscle.

Oscillations of the vocal cords (folds), which are caused by the current of exhaled air, produce sound. The strength and pitch of this sound depend on the speed of the air current and the tension of the vocal cords (Fig. 158). Speech is formed with participation of the lips, tongue and palate. The cavity of the larynx and the paranasal sinuses serve as sound resonators.

I n n e r v a t i o n of the larynx: superior and inferior laryngeal nerves (from vagus nerve), laryngopharyngeal branches (from sympathetic trunk).

B l o o d   s u p p l y: superior laryngeal artery (from superior thyroid artery), inferior laryngeal artery (from inferior thyroid artery).

Ve n o u s   o u t f l o w: superior and inferior laryngeal veins (into internal jugular vein).

L y m p h   o u t f l o w: deep cervical lymph nodes (internal jugular and prelaryngeal nodes).

Questions for revision and examination

1. Name the cartilages of the external nose and their location.
2. Describe the structure of the lateral wall of the nasal cavity, the nasal conchae and nasal meatuses.
3. Describe the structure and functions of mucosa of the nasal cavity.
4. Name the cartilages of the larynx and the means by which they articulate with each other.
5. Name the muscles which expand the vocal fissure and which contract it.
6. What muscles stretch the vocal cords? Describe the mechanism of this function.
7. Describe the inner surface of mucosa of the larynx. Explain what is the fibroelastic membrane of the larynx.

TRACHEA

The trachea (trachéa) is a hollow tubular organ, which serves as a passage for air to and from the lungs. In an adult the trachea begins at the lower margin level of the sixth cervical vertebra, where it connects with the larynx, and ends at the upper margin level of the fifth thoracic vertebra. The trachea lies in the anterior part of the neck (its c e r v i c a l   p a r t) and in the mediastinum of the thoracic cavity (its t h o r a c i c   p a r t). In front of the cervical trachea (its upper region) lie the lower part of the thyroid gland, pretracheal lamina of the cervical fascia, and sternohyoid and sternothyroid muscles. Behind the trachea lies the esophagus. At its sides lies a paired neurovascular bundle, which contains the common carotid artery, internal jugular vein and vagus nerve. Inside the thoracic cavity to the front of the trachea lies the arch of aorta, brachiocephalic trunk, brachiocephalic veins, beginning of the left common carotid artery and thymus gland. Behind it lies the esophagus, and at the sides — the right

and left mediastinal pleura. The average length of the trachea in an adult is
10–11 cm (ranges from 8.5 to 15 cm). At the level of the fifth thoracic
vertebra the trachea divides into the right and left bronchi (tracheal bifur-
cation) (Fig. 159). Inside the lumen of the bifurcation region there is a
semilunar prominence called the c a r i n a.

The wall of the trachea consists of a m u c o s a, s u b m u c o s a, f i -
b r o c a r t i l a g i n o u s   l a y e r and a d v e n t i t i a. The mucosa is lined
with pseudostratified columnar epithelium, which lies on a basement mem-
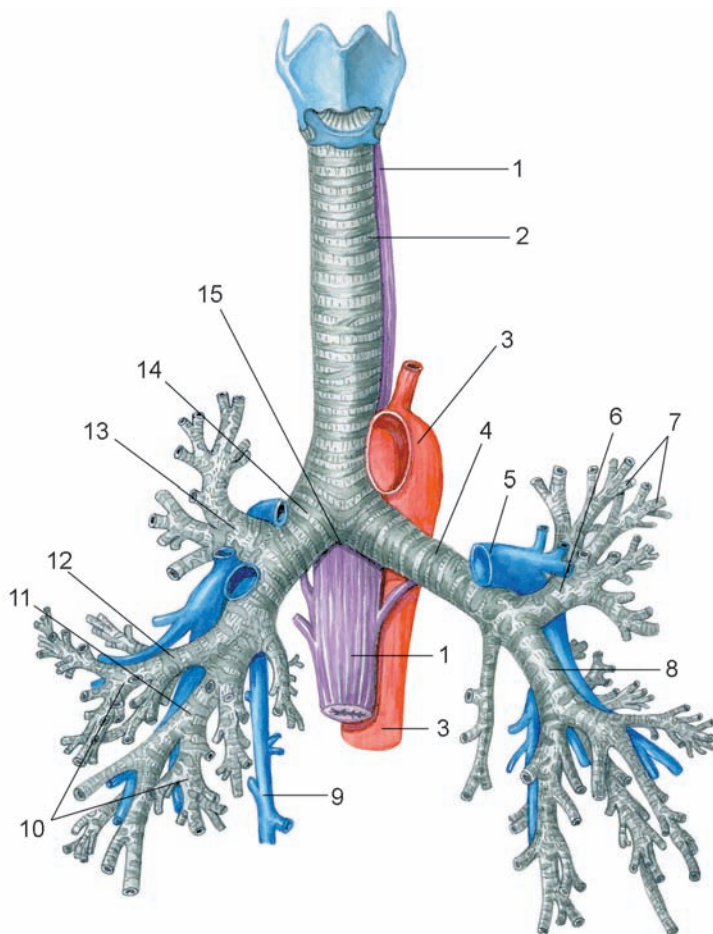
Fig. 159. Trachea and bronchi of right and left lungs. Anterior aspect.

1 — oesophagus; 2 — trachea; 3 — aorta; 4 — left main bronchus; 5 — left pulmonary artery; 6 —
left superior lobular bronchus; 7 — segmental bronchi; 8 — left inferior lobular bronchus; 9 — azy-
gos vein; 10 — segmental bronchi of inferior and middle lobes of right lungs; 11 — right inferior
lobular bronchus; 12 — right middle lobular bronchus; 13 — right superior lobular bronchus; 14 —
right main bronchus; 15 — tracheal bifurcation.

brane. Among its epitheliocytes are mostly ciliated cells, each of which may have up to 250 cilia. Movements of these cilia are directed upwards, toward the larynx. The epithelium contains a large number of goblet cells, which produce mucus. There are also basal (stem) cells, endocrinocytes (they secrete noradrenalin, serotonin, dopamine) and some other types of epitheliocytes. The lamina propria of mucosa contains a lot of longitudinally oriented elastic fibers and lymphoid tissue. Inside the lamina propria there are separate smooth myocytes with primarily circular orientation. The lamina propria mucosa is perforated by numerous excretory ducts of the glands, which lie inside the submucosa. The submucosa consists of loose fibrous connective tissue, and contains vessels, nerves and lymphoid nodules. The fibrocartilaginous layer is formed by 16–20 hyaline cartilages, connected by a n n u l a r   l i g a m e n t s. Each cartilage is shaped like an arch, which occupies two thirds of the circumference of the trachea. The annular ligaments, which connect and cover them, pass into their perichondrium. The posterior membranous wall of the trachea is formed by dense fibrous connective tissue with fascicles of myocytes. On the outside the trachea is covered by adventitia.

MAIN BRONCHI

The right and **left main bronchi (brónchi principáles)** begin at the bifurcation of the trachea, at the upper edge level of the C5 vertebra. They extend to the hila of the right and left lung, where they divide into lobar bronchi. Above the l e f t   m a i n   b r o n c h u s lies the arch of the aorta; above the right bronchus — the azygos vein. The r i g h t   m a i n   b r o n - c h u s is situated more vertically and has a shorter length (approximately 3 cm) than the left (4–5 cm in length). The right main bronchus is also wider (1.6 cm in diameter) than the left bronchus (1.3 cm in diameter). The walls of the main bronchi have the same structure as the trachea. Their structure is base on arches of cartilage (6–8 in the right bronchus and 9–12 in the left).

I n n e r v a t i o n of trachea and bronchi: branches of recurrent laryngeal nerves and sympathetic trunk.

B l o o d   s u p p l y: branches of the inferior thyroid artery, internal thoracic artery and thoracic part of aorta.

V e n o u s   o u t f l o w: into brachiocephalic veins.

L y m p h   o u t f l o w: lateral deep cervical (internal jugular) lymph nodes, pretracheal and paratracheal, superior and inferior tracheobronchial lymph nodes.

LUNGS

The right and **left lungs (pulmónes)** are situated in the corresponding halves of the thorax, within the pleural cavities. Situated between the lungs are the organs of the mediastinum. At the front, back and sides each lung adjoins the internal surface of the thoracic cavity. The shape of a lung resembles a cone flattened on one side and with a rounded a p e x. The right lung is 25–27 cm long and 12–14 cm wide. It is 2–3 cm shorter and 3–4 cm narrower than the left lung, due to a higher location of the right cupola of the diaphragm. Each lung has three surfaces. The d i a - p h r a g m a t i c   s u r f a c e is concave; it faces the diaphragm. The costal surface is convex and adjoins the inside of the thoracic wall. The vertebral part of this surface lies against the spine. The m e d i a l (m e d i a s t i n a l) s u r f a c e of the lung adjoins the mediastinum. Each lung has a base, which corresponds to the diaphragmatic surface, and an apex. The surfaces of the lung are limited by its margins. Between the c o s t a l and m e - d i a l s u r f a c e s is the a n t e r i o r   b o r d e r, and between these surfaces and the diaphragmatic surface is the i n f e r i o r   b o r d e r. On the anterior margin of the left lung is a recession called the c a r d i a c   n o t c h, limited at the bottom by the lingula of the left lung.

The right and left lungs have somewhat different projections onto the skeleton. The apex of the right lung in the front projects 2 cm above the clavicle and 3–4 cm above the first rib. In the back it projects at the level of the C7 spinous process. The anterior margin of the right lung extends from its apex to the right sternoclavicular joint. Then it passes through the middle the sternal angle. It extends downward behind the sternum (slightly left of the median line) to the cartilage of rib 4, where it continues into the inferior margin. Along the midclavicular line the inferior margin of the right lung corresponds to rib 6; on the anterior axillary line — to rib 7; on the middle axillary line — to rib 8; on the posterior axillary line — rib 9; on the subscapular line — rib 10; and on the paravertebral line — neck of rib 11. At the level of the eleventh rib the inferior margin turns upward, continuing into the posterior margin, which extends up to the head of the second rib.

The apex of the left lung protrudes 2 cm above the clavicle. From the apex the anterior margin extends to the left sternoclavicular joint, and then behind the body of the sternum down to the cartilage of rib 4. Then the anterior margin of the left lung deviates to the left and extends along the lower edge of the fourth costal cartilage until the parasternal line. From there it extends down to the sixth costal cartilage and abruptly turns, con-

tinuing into the inferior margin. The inferior margin of the left lung is situated approximately half a rib lower than that of the right lung. On the paravertebral line it continues into the posterior margin, which passes upward along the vertebral column. The posterior margins of the right and left lungs are approximately the same.

Each lung is divided into lobes by deep fissures. The right lung consists of three lobes (superior, middle and inferior), and the left consists of two (superior and inferior). In both lungs there is an oblique fissure, which extends from its posterior margin 6–7 cm below the apex (level of T3 spinous process) forward and down, to the anterior margin, where the later projects on the junction between rib 6 and its costal cartilage. From there the oblique fissure extends along the medial surface to the hilus of the lung. In both lungs the oblique fissure separates the inferior lobe. In the right lung there is also a horizontal fissure. It begins on the costal surface, approximately from the middle of the oblique fissure, where the latter crosses the middle axillary line. It extends across
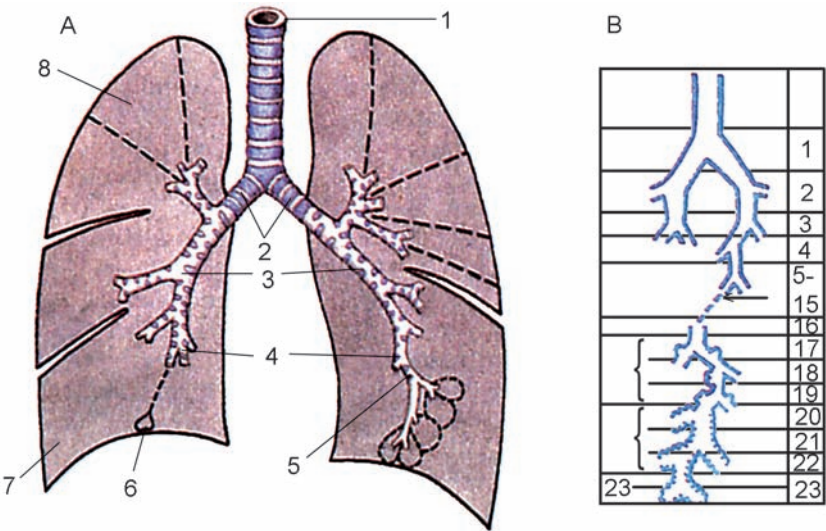
Fig. 160. Branching of bronchi of left and right lungs.

A — branching of bronchi within right and left lungs: 1 — trachea; 2 — main bronchi; 3 — lobular bronchi; 4 — segmental bronchi; 5 — lobule; 6 — acinus; 7 — inferior lobe of right lung; 8 — segment.

B — sequenced numeration of lobes: 1, 2 — main bronchi; 3, 4 — lobar and segmental bronchi; 5–15 — branches of segmental bronchi, lobular bronchi; 16 — terminal bronchiole; 17–19 — respiratory bronchioles; 20–22 — alveolar ducts; 23 — alveolar sacs.

the lung to its anterior margin, where it turns and passes to its hilus. The horizontal fissure separates the middle and superior lobes. The middle lobe of the right lung can be seen only from the front and medial sides. The lobes of the liver adjoin each other with their interlobar surfaces. On the medial surface of each lung is the hilum, which contains the root of the lung, formed by vessels, nerves and the main bronchus. In the hilus of the right lung the main bronchus is situated at the top, below it the pulmonary artery, and at the bottom — two pulmonary veins. In the hilus of the left lung at the top lies the artery, below it — the main bronchus, and at the bottom lie the veins. In the right lung the hilus is somewhat shorter and wider than in the left one.

In region of the hilus the main bronchus divides into three lobar, or secondary, bronchi (Fig. 160). When entering the superior lobe of the right lung the bronchus is situated above the lobar artery (branch of pulmonary artery), or epiarterially. In all other lobes of the right and left lungs the lobar bronchus lies beneath the lobar artery (hypoarterially). The lobar bronchi divide into smaller segmental (tertiary) bronchi, which continue to divide dichotomically. Division of bronchi and their nomenclature are shown in table 19.

Table 19. Division of bronchi inside the lungs.

Right main bronchus		Left main bronchus	
Lobar (secondary) bronchi	Segmental (tertiary) bronchi	Lobar (secondary) bronchi	Segmental (tertiary) bronchi
Superior	Apical	Superior	Apical
	Posterior		Posterior
	Anterior		Anterior
Middle	Lateral		Superior lingular
	Medial		Inferior lingular
Inferior	Superior	Inferior	Superior
	Medial basal		Medial basal
	Anterior basal		Anterior basal
	Lateral basal		Lateral basal
	Posterior basal		Posterior basal

Each segmental bronchus spreads through a separate segment of a lung (Fig. 161, 162). The nomenclature of the lung segments corresponds to names of the segmental bronchi (see table 18). In the center of each segment lie the segmental bronchus and artery. The segmental veins pass through the connective tissue layers, which separate neighboring bronchi. The segmental bronchi divide into subsegmental branches (9–10 consecutive divisions), which then are devidedinto lobular and interlobular bronchi.
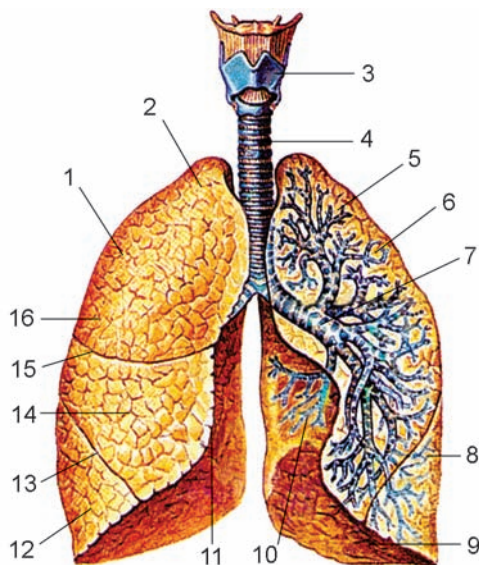
Fig. 161. Right and left lung. Left lung is incised in frontal sectioned. Anterior aspect.

1 — right lung; 2 — apex of lung; 3 — larynx; 4 — trachea; 5 — left lung; 6 — superior lobe;
7 — main bronchus of left lung; 8 — inferior lobe; 9 — inferior margin; 10 — cardiac notch;
11 — medial margin of right lung; 12 — inferior lobe; 13 — oblique fissure; 14 — middle lobe;
15 — horisontal fissure; 16 — superior lobe of right lung.

The structure of bronchi is similar throughout the whole b r o n c h i a l
t r e e. Their walls consist of m u c o s a, s u b m u c o s a, f i b r o c a r t i l a g -
i n o u s   l a y e r and a d v e n t i t i a. The mucosa is lined with ciliary epi-
thelium. The thickness of epithelium decreases as the bronchi become
smaller, and columnar epitheliocytes are gradually switched form colum-
nar to cuboidal. In the beginning the walls of the small bronchi are lined
with two-layer epithelium, which passes into simple. Among epithelio-
cytes there are goblet cells, endocrinocytes and basal cells. In distal sec-
tions of the bronchial tree there are also secretor secretory Clara cells,
which produce enzymes that break down surfactant (see below). The lam-
ina propria of mucosa contains a large amount of longitudinal elastic fi-
bers, which make the bronchial wall resilient. Inside the lamina propria lie
vessels, nerves and lymphoid tissue. The thickness of the lamina propria
(relative to thickness of the bronchial wall) increases from large bronchi
to small. Oblique and circular muscle fascicles of the muscularis mucosa
promote the formation of mucosal folds. These folds are present, however,
only in large bronchi, which are 5–15 mm in diameter. Aside from vessels,
nerves and lymphoid tissue the submucosa contains secretory sections of
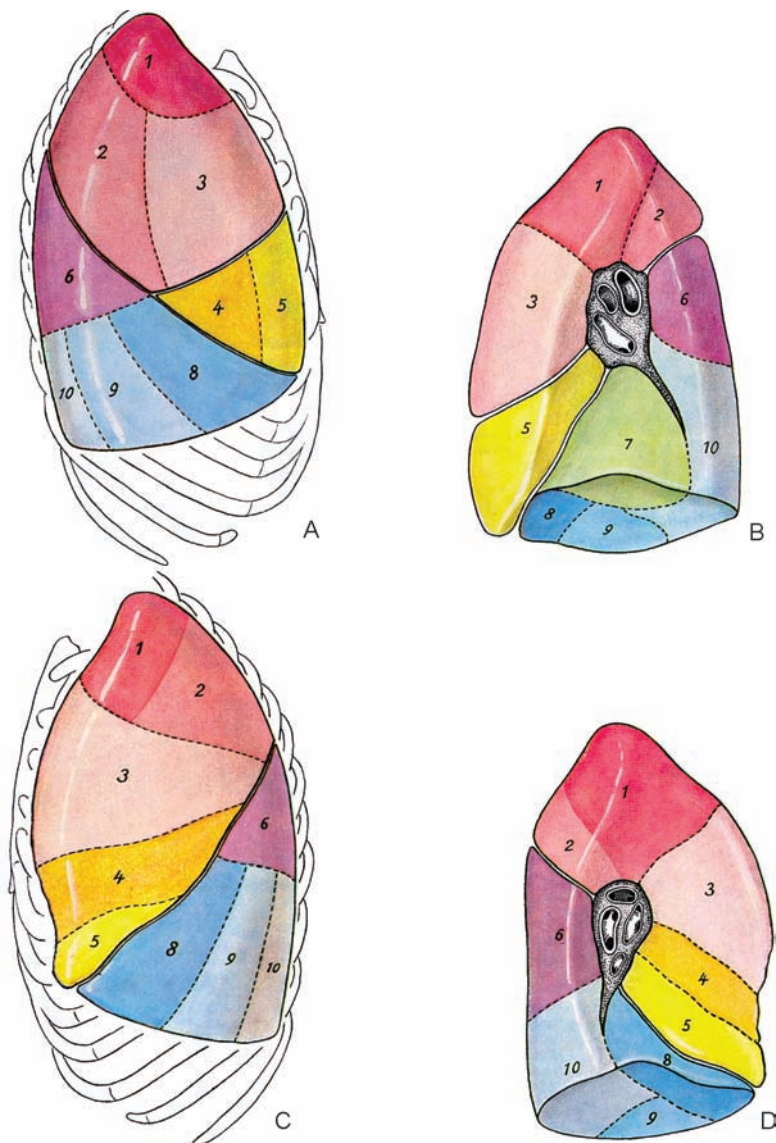
Fig. 162. Segments of right and left lungs.

A, B — right lung: 1 — apical segment (upper lobe)(C_I), 2 — posterior segment (C_{II}), 3 — anterior segment (C_{III}), 4 — lateral segment (C_{IV}); 5 — medial segment (C_V); 6 — apical segment (inferior lobe) (C_{VI}); 7 — medial (cardiac) basal segment (C_{VII}); 8 — anterior basal segment (C_{VIII}); 9 — lateral basal segment (C_{IX}); 10 — posterior basal segment (C_X);

C, D — left lung: 1 — apical segment (C_I); 2 — posterior segment (C_{II}); 3 — anterior segment (C_{III}); 4 — superior lingular segment (C_{IV}); 5 — inferior lingular segment (C_V); 6 — apical segment (inferior lobe) (C_{VI}); 7 — medial cardiac segment (C_{IX}); 8 — anterior basal segment (C_{VIII}); 9 — lateral basal segment (C_{IX}); 10 — posterior basal segment (C_X).

numerous mixed glands. These glands are absent only in small bronchi (less then 2 mm in diameter). The fibrocartilaginous layer in main bronchi contains closed cartilage rings. In lobar, segmental and subsegmental bronchi the walls contain cartilage plates. Lobular bronchi 1 mm in diameter contains separate segments of cartilage tissue, and bronchi of smaller size do not contain cartilage in their walls at all. The adventitia of the bronchi is made up of fibrous connective tissue, which is continuous with interlobular connective tissue.

After passing through the bronchial tree air enters the alveolar tree, which contains both conducting and respiratory components. The alveolar tree consists of structures called acini, which are the functional units of the lungs. Each lung contains approximately 150000 acini. An acinus is formed by one terminal bronchiole (branch of lobular bronchus), which branches into 14–16 primary respiratory bronchioles, which in turn branch into secondary and tertiary respiratory bronchioles. Tertiary respiratory bronchioles divide into alveolar ducts (100 mm in diameter). Each alveolar duct ends in two alveolar sacs. The walls of alveolar ducts and sacs have bubble-like protrusions, formed by vesicles called alveoli. One alveolar duct connects with approximately 20 alveoli. The diameter of an alveolus is approximately 280 mm. The total number of alveoli for both lungs reaches 600–700 million. The total surface area of alveoli fluctuates during inhalation and exhalation between 40 and 120 m^2. (Fig.163).

The a c i n u s has a complex structure. Respiratory bronchioles are lined with cuboid epithelium which contains primarily non-ciliated epitheliocytes and some ciliary and Clara cells. Beneath lies a thin discontinuous layer of smooth myocytes. Alveolar ducts are lined with squamous epithelium. The entrance into each alveolus is circled by thin fascicles of smooth myocytes. Alveoli are lined by two kinds of cells, including type I (respiratory, or squamous epithelial) and type II (large granular) alveolocytes. Among these cells there may also be macrophages. The respiratory alveolocytes form the majority of the alveolar lining. These cells are 0.1–0.2 mm thick; they contain a convex nucleus, numerous micropinocytotic vesicles and ribosomes. Other organelles are weakly developed. The process of gas exchange takes place through these alveolocytes. The large (granular) alveolocytes are situated in groups of two or three cells. These cells contain a large rounded nucleus and well developed organelles. Their apical surface has microvilli. These cells participate in formation of surfactant and act as a source of regeneration of the alveolar lining.

Surfactant is a complex substance composed of proteoglycolipids. It supports surface tension inside alveoli, preventing their collapse during
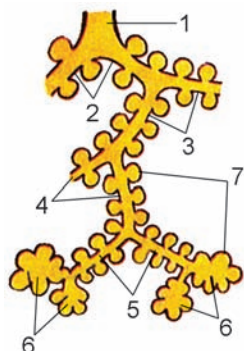
Fig. 163. Structure of acinus of lung.

1 — terminal bronchiole; 2 — alveolar bronchiole I; 3 — alveolar bronchiole II; 4 — alveolar bronchiole III; 5 — alveolar ducts; 6 — alveolar sacs; 7 — alveoli.

exhalation. Surfactant also has certain bactericidal qualities and penetration of liquid into the alveolar lumen.

The blood-air barrier, through which gas exchange takes place, is approximately 0.2–0.5 mm thick. It is formed by thin respiratory alveolocytes (90–95 nm), basement membrane of alveolocytes, basement membrane of blood capillaries and a thin layer of endotheliocytes (20–30 nm) (Fig. 164). The thickness of the two merged basement membranes is 90–100 nm. Capillaries are situated around alveoli in thick networks. Each capillary may adjoin one or several alveoli. Along with gas exchange the lungs participate in regulation of the acid-base balance, production of immunoglobulins by plasma cells, excretion of immunoglobulins into the lumen of respiratory passage and other functions.

I n n e r v a t i o n of the lungs: Branches of the vagus nerve and sympathetic trunk form the pulmonary plexus in the root of the lung. Branches of the pulmonary plexus penetrate inside the lung and form the peribronchial plexus.

B l o o d s u p p l y: The lungs receive arterial blood through bronchial branches (from thoracic part of the aorta)

V e n o u s o u t f l o w: bronchial branches into pulmonary, azygos and hemiazygos veins. The lungs also receive venous blood through pulmonary arteries. In the lungs this blood becomes oxygenated and looses carbon dioxide. Arterial blood flows through pulmonary veins into the left atrium.

L y m p h o u t f l o w: bronchopulmonary, inferior and superior tracheobronchial lymph nodes.

Questions for revision and examination

1. Describe the structure of the walls of the trachea and main bronchi.
2. Which organs adjoin the trachea and main bronchi in the thoracic cavity?
3. How long are the trachea and the main bronchi?
4. Name the segments of the right and left lungs.
5. What structures form a pulmonary acinus?
6. Describe the projections of the right and left lungs onto the skeleton.
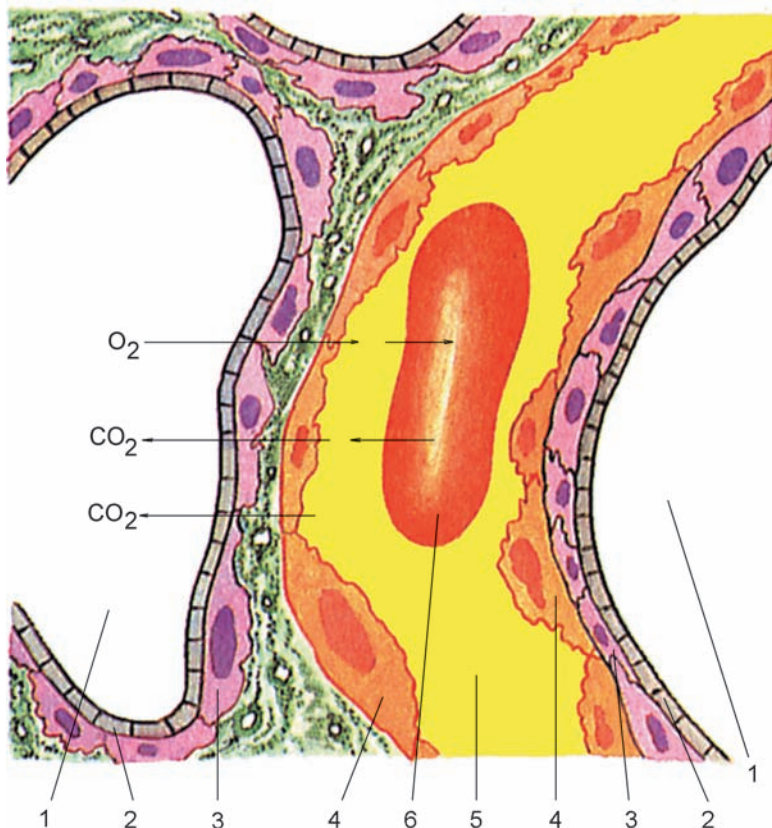
Fig. 164. Aerohaematic barrier of a lung.

1 — space of alveoles; 2 — surfactunt; 3 — alveocyte; 4 — endoteliocyte; 5 — space of capillary; 6 — erythrocytes within capillary space. Arrows show the way, how oxygen and dioxide pass across aerohaematic barrier.

PLEURA

The pleura (pléura) is a thin serous membrane, which consists of a parietal and visceral sheets (parietal and visceral pleurae). It is formed by a thin connective tissue base, which is covered by squamous epithelium (mesothelium), situated on a basement membrane. Cells of the mesothelium have numerous microvilli on their apical surfaces and weakly developed organelles. The connective tissue base is formed by a network of collagen and elastic fibers, separate fascicles of smooth myocytes and an insignificant amount of cell elements. The v i s c e r a l   p l e u r a covers the

lung from all sides, accretes with its surface and lines the surfaces of its fissures. It continues from the hilus of the lung onto the diaphragm as a fold, which forms the p u l m o n a r y   l i g a m e n t. The p a r i e t a l   p l e u r a is continuous with the visceral pleural sheet. It lines the internal surface of the thoracic cavity and the mediastinum. The parietal pleura is divided into the costal, diaphragmatic and visceral parts. The c o s t a l   p l e u r a lines the inside surfaces of the ribs and intercostal spaces. In the front near the sternum, and in the back near the spine the costal pleura continues into the mediastinal. The m e d i a s t i n a l   p l e u r a covers the organs of the mediastinum. It extends from the inside surface of the sternum to the lateral surfaces of the spine. It is continuous with the pericardium. In the region of the lung root the mediastinal pleura continues into the visceral pleura. At the level of the head of rib 1 the mediastinal and costal pleurae connect, forming the p l e u r a l   c u p u l a. From the front and medially this cupola is adjoined by the subclavicular artery and vein. At the bottom the costal and mediastinal pleurae continue into the d i a p h r a g m a t i c   p l e u r a, which covers the diaphragm, excluding its central regions, which are accreted with the pericardium. Between the parietal and visceral pleurae there is a narrow space called the p l e u r a l   c a v i t y (c ávu m   p l é u r a e).

This cavity contains a small amount of serous fluid, which moistens the pleural membranes, allowing them to glide against each other more easily during breathing. In places of transition between the mediastinal and diaphragmatic pleurae the pleural cavity has recessions called pleural recesses, or sinuses, which serve as reserve spaces. The c o s t o d i a - p h r a g m a t i c   r e c e s s (recéssus costodiaphragmáticus) is situated at the transition between the costal and diaphragmatic pleurae. Its deepest part (9 cm) corresponds to the middle axillary line. The p h r e n i c o m e - d i a s t i n a l   r e c e s s (recéssus phrenicomediastinális) is situated at the transition between diaphragmatic and mediastinal pleurae in the form of a small sagittal fissure. The c o s t o m e d i a s t i n a l   r e c e s s (recéssus cos- tomediastinális) is a small fissure situated in the transition region between the anterior costal and mediastinal pleurae.

The right and left cupolas of the pleura extend 1.5–2 cm above the clavicle. Its anterior and posterior borders correspond to the borders of the lungs (Fig. 165, 166, 167). The inferior border of the pleural cavity lies one rib (2–3 cm) lower than the inferior margin of the lung. On the midclavicular line it corresponds to rib 7; on the anterior axillary line — to rib 8; on the middle axillary line — to rib 9; posterior axillary line — to rib 10; scapular line — to rib 11; and at the level of rib 12 it continues into the posterior border. The anterior borders of the pleura are parallel to each other between ribs 2 and 4. Above and below they diverge, forming inter-

pleural fields. The superior interpleural field is situated behind the manu-
brium sterni and contains the thymus gland. The inferior interpleural field
is triangular; it lies behind the inferior half of the sternum and adjacent
ribs. It contains the part of the pericardium, which adjoins directly to the
anterior thoracic wall.

MEDIASTINUM

The mediastinum (mediastinum) is a complex of organs, which are
situated between the sternum, vertebral column and right and left medias-
tinal pleurae. At the top it is limited by the superior aperture of the thorax,
and at the bottom by the diaphragm. The mediastinum is divided into
superior and inferior sections. The border between these sections is the
plane drawn through the sternal angle and intervertebral disc between T4
and T5 vertebrae. The **superior mediastinum** contains the thymus gland,
left and right brachiocephalic veins, beginning of the superior vena cava,
arch of the aorta, beginning of the brachiocephalic trunk, left common
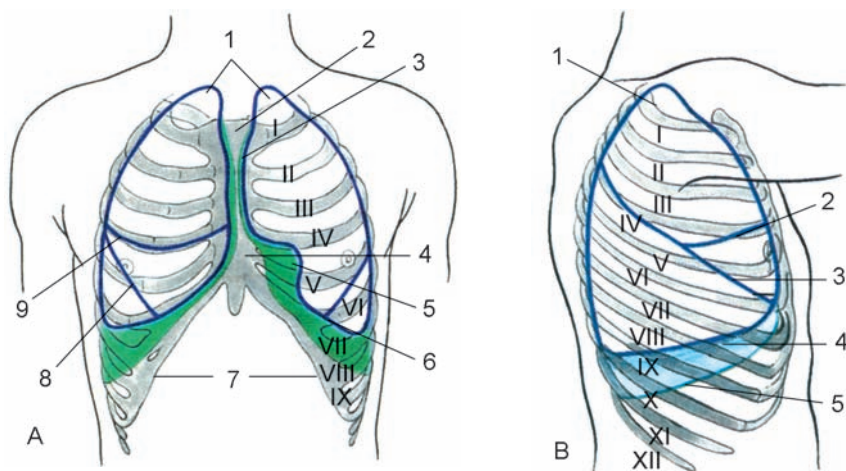
Fig. 165. Projections of borders of lungs and parietal pleura.

Part of pleural cavity between inferior margins of lungs and inferior border of parietal pleura is of
green color. Rome digits ribs are enumerated.

A — anterior aspect: 1 — apex of lung; 2 — superior interpleural area; 3 — anterior margin of lung;
4 — inferior interpleural area; 5 — cardiac notch; 6 — inferior margin of lung; 7 — inferior border of
parietal pleura; 8 — oblique fissure; 9 — horisontal fissure (of right lung). B — lateral aspect: 1 —
apex of lung; 2 — horisontal fissure; 3 — oblique fissure; 4 — inferior margin of lung; 5 — inferior
border of parietal pleura.
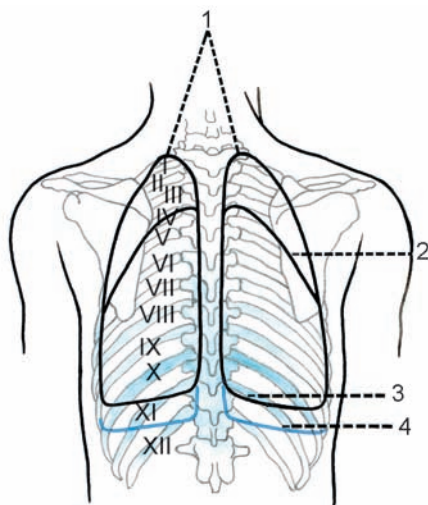
Fig. 166. Projections of borders of lungs and parietal pleura. Posterior aspect.

A part of pleural cavity between inferior margins of lungs and inferior border of parietal pleura have blue color. Rome digits enumerate ribs.

1 — apex of lung; 2 — oblique fissure; 3 — inferior margin of lung; 4 — inferior margin of parietal pleura.
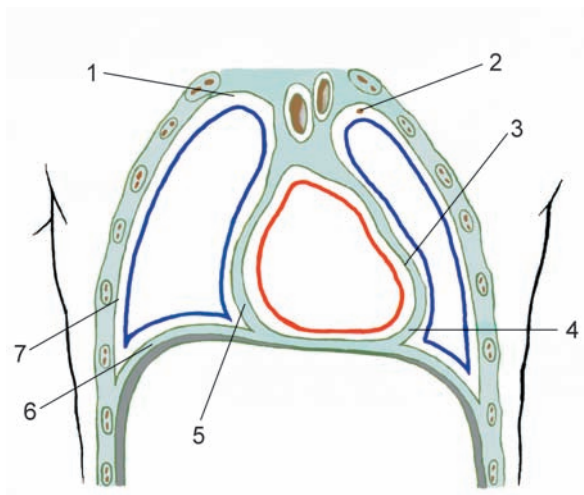
Fig. 167. Pleural and pericardial cavities; shematic section in frontal flat**.**

1 — left lung; 2 — pleural cavity; 3 — pericardial cavity; 4 — diaphragm; 5 — costodiaphragmatic sinus; 6 — mediastinal pleura; 7 — right lung.

carotid and left subclavicular arteries. It also contains the trachea, part of the esophagus, thoracic duct, sympathetic trunk, vagus and phrenic nerves. The **inferior mediastinum** consists of an anterior, middle and posterior parts. The **anterior mediastinum** is situated between the body of the sternum and the anterior surface of the pericardium. It contains the internal thoracic arteries and veins, parasternal and prepericardial lymph nodes. Situated inside the **middle mediastinum** are the heart and pericardium, beginning parts of the aorta and pulmonary trunk, end parts of the superior and inferior venae cavae, main bronchi, pulmonary arteries and veins, phrenic nerves, pericardiophrenic vessels, inferior tracheobronchial and pericardial lymph nodes. The **posterior mediastinum** contains organs, situated behind the pericardium. This includes the thoracic part of the aorta, azygos and hemiazygos veins, sections of the right and left sympathetic trunks, greater and lesser splanchnic nerves, vagus nerves, esophagus, thoracic duct and prevertebral lymph nodes.

In clinical practice the mediastinum is divided into the anterior and posterior sections, which are divided by a frontal plane, drawn through the roots of the lungs. The anterior mediastinum contains the heart, pericardium, arch of the aorta, thymus gland, phrenic nerves, pericardiophrenic and internal thoracic arteries and veins, and parasternal, mediastinal and superior phrenic lymph nodes. The posterior mediastinum contains the esophagus, thoracic part of the aorta, thoracic duct, azygos and hemiazygos veins, vagus and splanchnic nerves, sympathetic trunks and posterior, mediastinal and prevertebral lymph nodes.

DEVELOPMENT OF THE RESPIRATORY SYSTEM

Development of the external nose and nasal cavity is associated with formation of the fascial skull, oral cavity and olfactory organs of the embryo. A sac-like protrusion forms in the front, at the border between the pharyngeal and truncal guts. It continues to grow in the ventrocaudal direction, forming the laryngotracheal tube. Its upper end is connected to the future pharynx. On the fourth week of embryogenesis the lower end of this tube divides into the left and right bronchial buds. The proximal part of the laryngotracheal tube develops into epithelium and glands of the larynx. Its distal part forms epithelium and glands of the trachea. The right and left bronchial buds form the epithelium of the bronchi and lungs. During formation of the larynx its endoderm derivatives (primary gut) become integrated with the surrounding mesenchyme. The mesenchyme gradually develops into connective tissue, cartilage, musculature, blood and lymph vessels. Germs of future laryngeal cartilages and muscles appear during the fourth week of development. The cartilages of the larynx develop from

the second and third branchial arches. The muscles develop from a common muscle sphincter, situated to the outside of the pharyngeal gut. Secondary (lobar) bronchi begin to form during the fifth week. The lobar bronchial buds continue to divide into future segmental bronchial buds, which, in turn, form the rest of the bronchial tree. Bronchioles form between months 4 and 6, and alveolar ducts and sacs — between months 6 and 9. At the moment of birth the bronchial and alveolar tree consists of 18 orders of branches. After birth it continues to grow (up to 23 orders of branches) and differentiate.

The visceral and parietal pleura develop from the splanchnopleura and somatopleura, respectively. Between them forms the pleural cavity.

AGE CHARACTERISTICS OF THE RESPIRATORY SYSTEM

Nasal cavity. In newborns the nasal cavity is narrow, with a height of 17–18 mm. The nasal conchae are thick, and the nasal meatuses are almost undeveloped. The paranasal sinuses are absent, with the exception of the maxillary sinus. The middle nasal meatus appears at the age of 6 months. The inferior meatus forms at age 2, and the superior — after the age 2 or 3. The frontal sinus develops during the second year of life. The sphenoid sinus appears by age 3; cells of the ethmoid bone develop between ages 3 and 6. By 8–9 years the maxillary sinus takes up almost the entire body of maxilla. The paranasal sinuses are almost completely developed by ages 10–14. The nasal cavity reaches its final size by age 18–20. During senescence the cartilages of the nasal cavity undergo partial calcification.

Larynx. A newborn child has a short, wide larynx, which has the shape of a funnel. It is situated higher than in an adult (at the level of C2–C4 vertebrae), and its superior aperture is relatively wider. The vestibule is short; the vocal fissure is situated at a high level and has the length of 6.5 mm. The cartilages of the larynx in newborns are thin, the Adam's apple is absent, and the epiglottis extends above the root of the tongue. This position characteristic allows infants to breath and swallow (drink) simultaneously, because during swallowing the milk flows along the sides of the epiglottis. The muscles of the larynx in newborns are weakly developed. The larynx grows most intensively during the first four years of life. After age 6–7 it begins to develop sexual characteristics, such as the larger size, the Adam's apple, and the longer vocal chords in boys. The larynx undergoes active growth after ages 10–12. As it grows its upper and lower borders descend. It reaches its adult position after ages 17–20. The cartilages of the larynx retain their flexibility until age 35–50. During senes-

cence almost all cartilages (except for the epiglottis) begin to calcify, and the number of glands in the larynx decreases.

Trachea and main bronchi. In newborns the trachea is 3.2–4.5 cm long and less than 0.8 cm wide. The length of the right main bronchus is 0.6 cm, and of the left — 0.8 cm. Their mucosa is delicate. It contains a small amount of glands. The cartilages are soft and flexible, and the membranous wall is relatively wide. The trachea and main bronchi grow intensively during the first year, after which their growth slows down. By age 3–4 the width of their lumen increases by more than two times. Their growth intensifies during puberty. During the same period the upper and lower borders of the trachea descend. After ages 60–70 the cartilages of the trachea calcify and become brittle. The number of glands of the trachea and bronchi and their sizes decrease.

Lungs. The lungs of a newborn have a conoid shape. The superior lobes are relatively small, while the inferior lobes are comparatively large. The apexes of the lungs are situated at the level of rib 1, and the inferior margin is situated one rib higher than in an adult. The bronchial tree is formed. The number of alveoli inside the acini is small. During the first year of life there is significant growth of the bronchial tree and formation of new bronchioles, alveolar ducts and alveoli. The lungs undergo most intensive growth during puberty. The formation of alveolar ducts ends by age 9, and of alveoli — by age 12–15. The lung parenchyma is completely formed by age 20–25. The bronchial tree reaches maximal size between ages 35–40. After age 50 the length and diameter of the bronchi decreases. Sometimes their walls form diverticula. During senescence the alveoli increase in size and part of the interalveolar septa disappears. The connective tissue of the lungs proliferates, while the content of parenchyma and the volume of the lungs decrease. The inferior margin of the lungs in elderly people is situated 1–2 cm lower than at ages 30–40.

Pleura. During senescence the pleural cavity may contain adhesions between the parietal and visceral pleurae. The inferior margin of the pleura in elderly people projects lower than during ages 30–40.

VARIANTS AND ANOMALIES OF THE RESPIRATORY SYSTEM

External nose. The number of cartilages of the external nose varies. Often some of them are absent. In 20 percent of cases, near the posterior part of the nasal septum, there are a right and left vomeronasal cartilages. The shape and size of the nose and nostrils are highly variable.

Nasal cavity. Situated in the mucosa, which covers the anterior nasal spine, there is often a small blind canal called the vomeronasal (Jacobson's) organ. This canal is directed upward and to the back, and is a rudi-

ment of the Jacobson's organ of vertebrates. Behind and somewhat lower than the Jacobson organ there is occasionally a blind incisive (Stensen's) duct. It is a rudimentary structure, situated inside the incisive canal. In 70 percent of cases the nasal septum is slightly deviated to the right or left. Occasionally there is a significant deviation. The development of the nasal conchae and depth of the nasal meatuses may vary. Often there is an additional foramen behind the semilunar fissure, which communicates the middle nasal meatus with the maxillary sinus.

Larynx. The extent of calcification of laryngeal cartilages varies between individuals. Their size and shape may also have significant differences. Often the superior horns of the thyroid cartilage are absent. There is occasionally a small foramen 1–6 mm wide in one or both of its plates. The cricoid cartilage may have an additional tubercle (marginal denticle), situated on the inferior margin of its arch. The triticea cartilages may be absent, doubled or increased in size. Sometimes the cricothyroid articulations are absent. Mobility in joints of the larynx may vary. Its ligaments may be developed to various extents. Most inconstancy is noted for the muscles of the larynx. In 10 percent of cases there is a thyrotracheal or a cricotracheal muscle. In 3 percent of cases there is an unpaired transverse thyroid muscle. Very rarely there is a lateral epiglotticothyroid muscle, which raises the thyroid gland. In 20 percent of cases there is a cricoepiglottic muscle; in 9 percent — a depressor muscle of the arytenoid cartilages, in 16 percent — additional fascicles of the thyroarytenoid muscle. In 22 percent the lateral thyroarytenoid muscle is absent. In the anterior half of the ventricle of the larynx, on one or both sides, there is sometimes a small excavation called the laryngeal appendix. Its shape and size are variable.

Trachea. The length and width of the trachea are variable. The number of its cartilages ranges from 12 to 22. The shape of cartilages often has individual peculiarities. Sometime in the place of bifurcation the trachea divides into three main bronchi (trifurcation). Occasionally there are congenital fistulae between the trachea and esophagus. There is sometimes a thyrotracheal bursa between the thyroid gland and the trachea. In rare cases there is an arototracheal bursa between the trachea and aorta.

Lungs. The lungs may vary in shape and size. Often there are additional lobes in one or both lungs (up to 6 lobes in a lung). Sometimes separate bronchi extend from the main bronchi to the apexes of the lungs. Very rarely, when there are defects of the diaphragm, the lung may have an accessory lobe protruding into the abdominal cavity. The amount of connective tissue in the lungs, and the number of acini and their components may vary.

Pleura. The depth and size of pleural recesses are variable. Often there are adhesions between the parietal and visceral pleurae. In 7 percent of cases the right and left sheets of the mediastinal pleura are linked in the front behind the sternum, forming a mesocardium.

Mediastinum. The mediastinum may be narrow, or, on the contrary, unusually wide, which depends on the configuration of the thorax. The topography of the thoracic and abdominal organs may be partially or totally inverted.

Questions for revision and examination

1. Describe the structure of the pleura and its locations inside the thoracic cavity.
2. What part of the pleura is called the pulmonary ligament?
3. Name the pleural recesses. Where is each of them located?
4. Compare the projections of the lungs and the pleural cavity onto the surface of the body. How are their borders different?
5. What anatomical structures of the thoracic cavity form the mediastinum?
6. What sections is the mediastinum divided into? What organs are situated inside each of these sections?
7. What variants and anomalies of respiratory organs do you know?

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TEXTBOOK OF HUMAN ANATOMY

For medical students

Volume 1

М.Р. Сапин, Л.Л. Колесников, Д.Б. Никитюк

АНАТОМИЯ ЧЕЛОВЕКА

Учебное пособие для студентов медицинских вузов
(на англ. языке)

Книга 1